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"MV ARCTIC"

1981 LATE SEASON DATA COLLECTION AND INSTRUMENTATION

VOLUME I - MAIN REPORT

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Prepared for:

TRANSPORTATION DEVELOPMENT CENTRE
1000 Sherbrooke Street West
Montreal, Quebec, H3A 2C3

Submitted by:

H. Blount
I.F. Glen
M. Steele

ARCTEC CANADA LIMITED
311 Leggett Drive
Kanata, Ontario, K2K 1Z8

The contents of this report reflect the views of the authors and not necessarily the official views or policies of the Transportation Development Centre.

The Project Team from ARCTEC CANADA LIMITED was composed of:

°I.F. Glen

°H. Blount

°M. Steele

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17. Abstract

This is the report of the operation of the M.V. ARCTIC data acquisition system during the latter part of the 1981 data collection season. During the period, system maintenance levels continued to be high. Principal problems were computer losses due to overheating and failed integrated circuit boards. Gauge drift and video camera problems also were of importance.

A large quantity of data was collected, much of it in heavy ice conditions. Preliminary analysis of this data concentrated on more significant ice interactions, and a new approach to presenting trends in statistical data is presented. A number of sampling patterns were tried and are compared.

A section of the report describes the interpretation of the data. Suggestions for techniques to validate data during further analysis are made. A comparison with analogue signals is made. Results indicate that local hull stress levels while backing and ramming in multi-year ice are high - exceeding yield in some instances, 2 and 3 times those during transit operations in heavy ice, and up to 6 times greater than those experienced while transiting level 1st year ice. It is noted that following in the track of an icebreaker also gives rise to high loading.

A system operator's maintenance and trouble shooting guide has been compiled for use should further data collection be pursued, but the authors recommend this not take place with the current data acquisition system, but only after the value of data collected to date has been assessed.

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17. Résumé

Cet ouvrage traite des activités reliées au mécanisme d'a quisition de données du navire M.V. ARCTIC au cours de l'exercice saisonnier 1981.

Le niveau d'entretien du système a continué d'être élevé durant ce temps. La surchauffe et la défectuosité des modules à circuits intégrés ont été la source prédominante de problèmes, quoique la fluctuation des cellules de mesure de déformation et le bris de caméras vidéo furent des entraves non moins sérieuses.

Un grand nombre de données ont été recueillies dont une quantité importante a été enregistrée lors de conditions sévères des glaces. Les aspects les plus révélateurs des réactions coque et glaces ont fait l'objet principal de la première analyse. Une nouvelle technique pour l'identification de la tendance des résultats statistiques y est introduite. Un certain nombre de modèles d'échantillonnage a été essayé et comparé.

Dans un autre chapitre, on traite de l'interprétation des données et l'on suggère des techniques de validation par utilisation d'analyses subséquentes. On y fait aussi l'analyse comparative de données produites par signal continu.

Les résultats enregistrés indiquent que lorsque le navire a dû éperonner à répétition des banquises vieilles de plusieurs années, les bordées furent soumises à des efforts locaux très élevés souvent même, au-delà de la limite d'élasticité. On a constaté que le niveau des efforts pouvait atteindre jusqu'à six fois la valeur moyenne observée au cours du bris de glaces saisonnières de première année. On a aussi relevé de très grandes contraintes locales en suivant un brise-glace dans son sillon.

Un guide de l'opérateur pour l'entretien et le dépannage a été rédigé advenant la nécessité de collecter des données supplémentaires. Cependant, cet organisme ne conseille pas d'utiliser le présent système pour acquérir plus de données tant qu'on n'aura pas fini d'évaluer et de juger la valeur du matériel déjà recueilli.

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SUMMARY

This report describes the voyages and data collected during the operations of MV ARCTIC in the summer and fall of 1981. The report provides information concerning the extent and quality of data collected by the onboard data acquisition system while transitting ice en route to and from Nanisivik, and the results of preliminary analysis performed on that data. Conclusions and recommendations for system operation, maintenance and data analysis are provided.

The period saw a high level of system maintenance activity in order to keep the system operating under the unsuitable environmental conditions. The ship experienced encounters with multi-year ice in November and data was recorded while the ship experienced heavy loading resulting in some hull damage. A total of 50 tapes representing 80 hours of performance data were recorded.

Data was played back in a statistical form during the latter part of the voyage and preliminary analysis has been carried out on this data. This analysis includes discussion of the assumptions necessary in interpreting the recorded data. These discussions include comparison with analogue signals recorded onboard. Trends between recorded data were examined and it is proposed that this type of analysis be utilized on the remainder of the data base.

Several cases of hull yield were recorded and stress values beyond yield were noted. Results from data collected during operations in the track of an icebreaker show significant ice loading activity, while loads on the gauged hull during dedicated head-on ramming tests were negligible.

The report concludes that continued operation of the system should be subject to review in light of the system capabilities and after assessment of the data recorded to date. Nevertheless the use of this vessel for continued research into ship/ice interaction is considered valuable in view of its configuration.

1. INTRODUCTION

"MV ARCTIC" is a general purpose ore carrier built to Arctic Class 2 under the current Arctic Shipping Pollution Prevention Regulations. She has an installed data acquisition system which has been used during the several annual voyages into the Canadian Arctic, to record data on the performance of the ship systems in ice, including the response of the hull to ice impacts. The purpose of installing this system was to evaluate icebreaking features of the vessel for guidance in future designs and to collect data for use in updating the Arctic Shipping Pollution Prevention Regulations. These regulate design requirements for a ship proceeding in Canadian Arctic waters, and cover such aspects as hull strength, propulsion system power and strength, rudder and steering system requirements, etc.

For the 1981 season reported herein the data collection program was divided into two - maintenance and operations. The operations were further split between two contractors covering the two halves of the summer season of five voyages. ARCTEC CANADA was awarded the operations contract for the 1981 late season. The time available to check out the system prior to operation was limited, and the system was accepted in the knowledge that deficiencies had been identified. A separate maintenance contract was negotiated, and it was the intent that the operator carry out daily maintenance onboard and identify problems which could not be handled onboard to appointed maintenance contractor who was not onboard during the ship passages.

The operator's role onboard the ship was to collect data when in ice covered waters with the computer and video masthead camera as well as to maintain comprehensive logs on ship activities and ice conditions. When not collecting ice data, the operator's function was to perform as much analysis of collected data as possible with the onboard analysis software. The end objective, satisfied by this report, was to assemble a well documented data package with preliminary analysis of data and to make recommendations for future system operations and data analysis. The collected data has been documented in a form suitable for subsequent, more detailed analysis if desired.

During this period of data collection the ship experienced greater interactions with multi-year ice than in other recent periods, not only during the dedicated periods, but on the last run out of Nanisivik which was achieved one day before 'closing' of the zone. Since it is the belief of the authors that it is interaction with multi-year ice that is of most significance to update of the CASPPR, and that much level ice transit data has been reported previously, this report concentrates on data analysis of these more significant incidents. Indeed little level ice transit was experienced this time.

This report contains a summary of the ship's activities, a discussion of computer outputs, preliminary analysis from statistical data, analysis of data collected during controlled ramming of multi-year ice during which hull damage occurred, analysis of data from an analogue recorder provided by ARCTEC CANADA LIMITED, and comments on future system operations and data reduction techniques. In addition we provide observations on the system based on our experience in this field. In the appendices are listed the logs along with discussion of maintenance, operating and data reduction aspects and a summary of the system status including sampling patterns. An operators troubleshooting guide is found in Volume II, Appendix F.

2. VOYAGE SUMMARY

It is the intent of this summary to outline the activities of the ship during the late shipping season. Monthly progress reports were submitted in September, October and November in which detailed logs of the ship operations were submitted. These reports are not repeated here but significant aspects are summarized below, in the daily activity log in Appendix A and the maintenance log of Appendix B.

On August 28, 1981 the MV ARCTIC arrived at Nanisivik, midway through her third round trip of the Atlantic crossing of 1981, damaging the bow while docking. ARCTEC CANADA LIMITED engineers inspected the data acquisition system and submitted an acceptance report to TDC [1]. This acceptance was subject to a number of reservations which recognized the system status, early season problems and time available to perform adequate calibration checks. Following this period one operator was left with the ship for the subsequent Trans-Atlantic crossing.

Following completion of temporary repairs to the ship at Nanisivik on September 4th, the ship loaded and sailed for Antwerp on September 6th, arriving September 16th. After unloading, it took passage to Amsterdam and docked for repairs, leaving Amsterdam in ballast at 0430 on September 26th for Nanisivik. Although bergs were sighted no ice was encountered on either eastbound or westbound voyages.

Recordings were made of system parameters in various sea conditions, the operator experimenting with various sampling patterns. A total of six hours were recorded.

On October 1st the ship was rounding Cape Farewell westbound at 16 knots en route to Nanisivik. A seized piston on October 3rd delayed entry at Nanisivik until October 8th, at which time the system operator was changed. The ship sailed from Nanisivik on October 9th sighting only limited ice on the east coast. The ship arrived in Antwerp on October 18th with no maintenance representative necessary, and sailed again westbound on October 21st. Some tapes were recorded during propulsion tests carried out for LIPS personnel. On November 3rd the ship arrived at Broughton Island where a team from Melville Shipping Limited and Ship Safety were picked up for a few days of dedicated testing in multi-year ice. The ship rendezvoused with CCGS LOUIS S. ST. LAURENT on November 4th and ice trials were performed in first and second year ice with 0 to 1/10 multi-year. These were primarily ramming tests at 2-5 knots into multi-year ice, to investigate hull girder response. An analogue tape recorder was rigged temporarily in the fore-end during these tests.

The ship arrived Nanisivik on November 9th and sailed with zinc and lead concentrate November 10th bound for Antwerp. On this outbound trip, the MV ARCTIC encountered the heaviest ice conditions of the season taking nine days to reach Cape Farewell. The ship was forced to stop for the night four times; three times to let ice conditions ease and once to carry out engine repairs. The heaviest concentrations of multi-year ice were found transiting Lancaster Sound from Admiralty Inlet to Navy Board Inlet and leaving Pond Inlet. Navigation was especially difficult entering Navy Board Inlet due to a large number of icebergs grounded at the mouth of the inlet.

Data acquisition was closed down for the season on November 16th in Davis Strait, with pancake ice present, in order to use the limited time available during the remaining passage to carry out data reductions. This was performed on a round-the-clock basis until the ship reached Antwerp on November 27, 1981.

Figure 2.1 illustrates the ship's activities for the fall season, Figure 2.2 summarizes the final trip and Figures 2.3 to 2.5 are photographs of ice conditions at the points indicated on the map. Additional photographs of the ship's hull, showing damage probably acquired during ice trials, are found in Appendix E.

FIGURE 2.1

SUMMARY OF 1981 SEASON VOYAGES

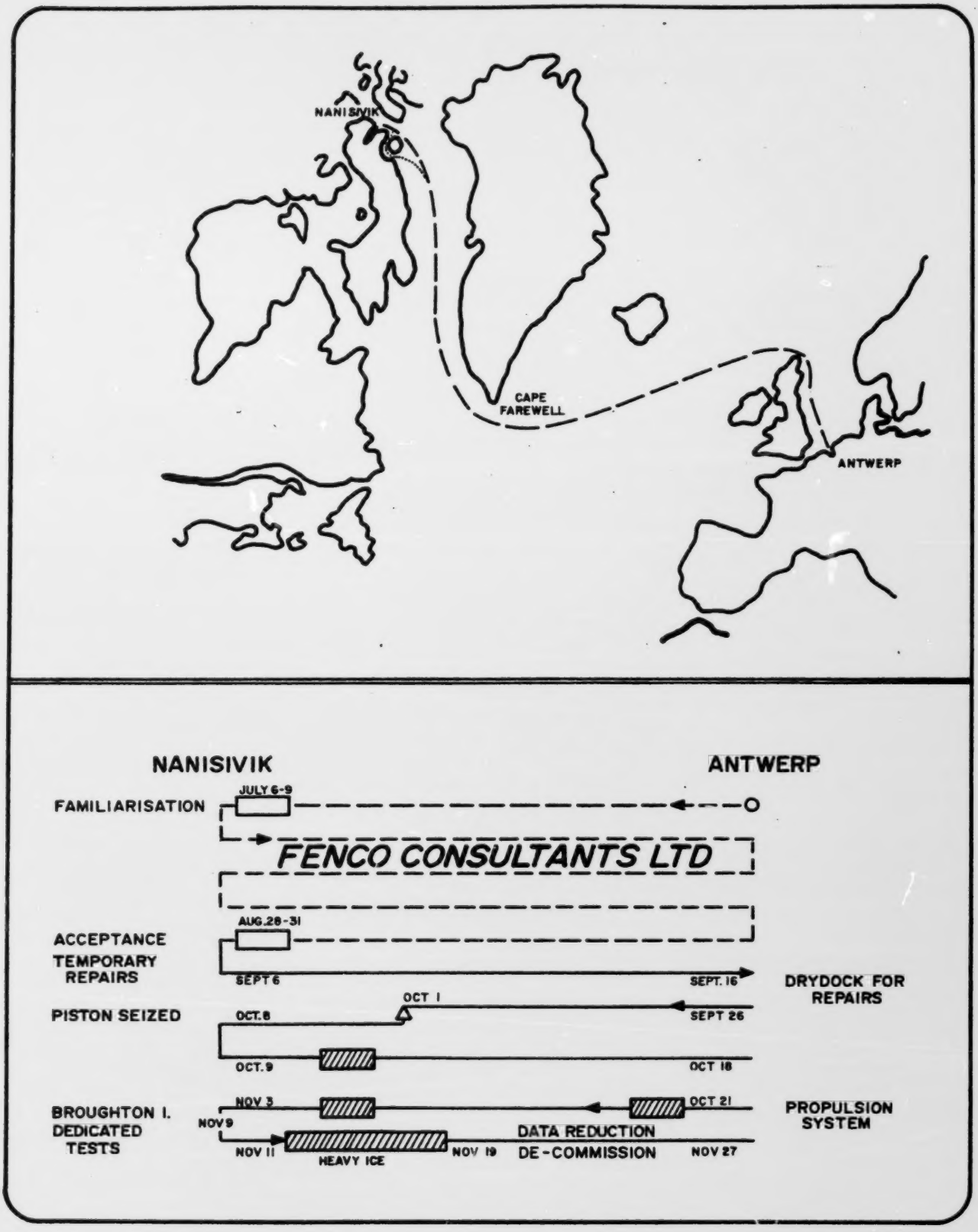
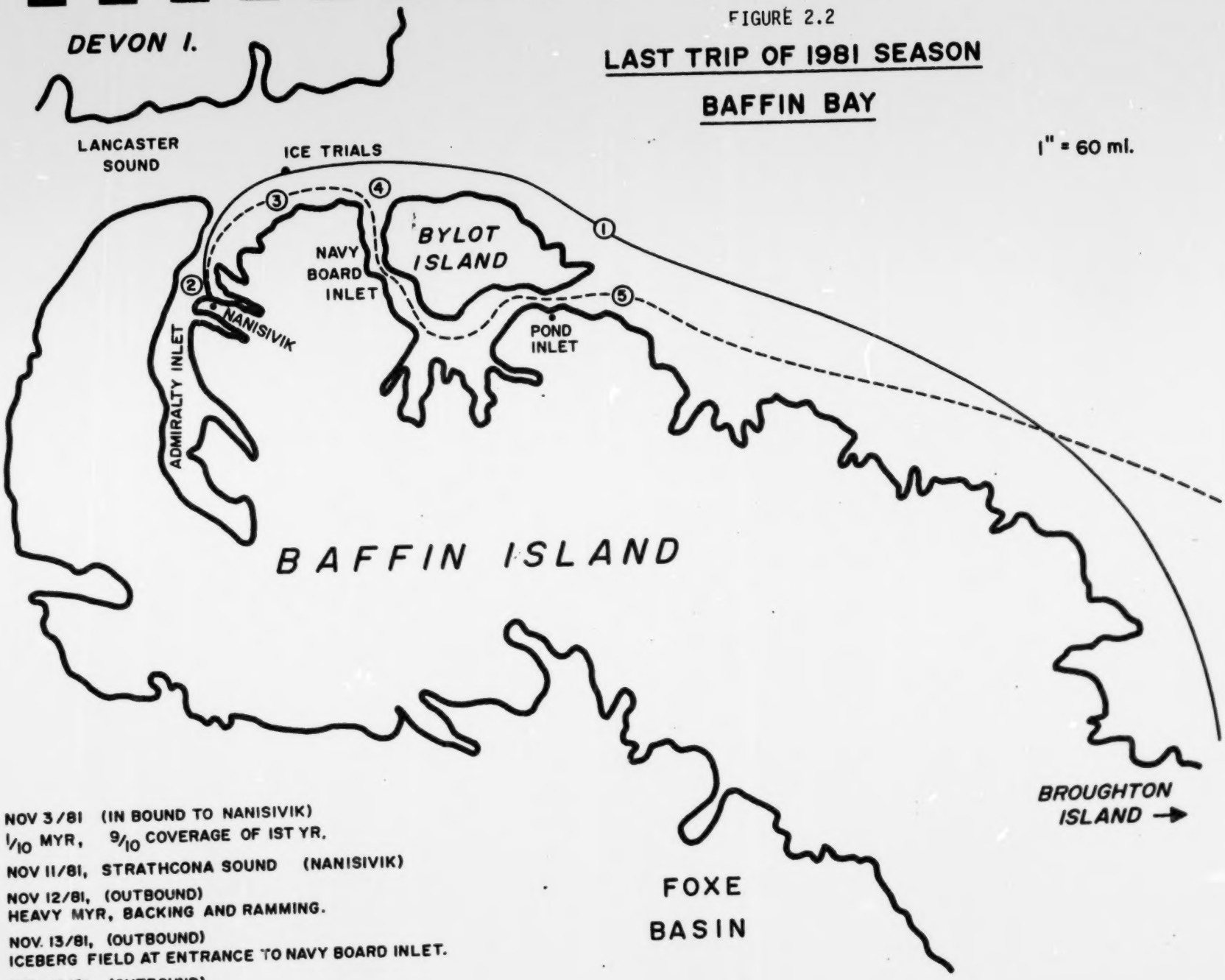


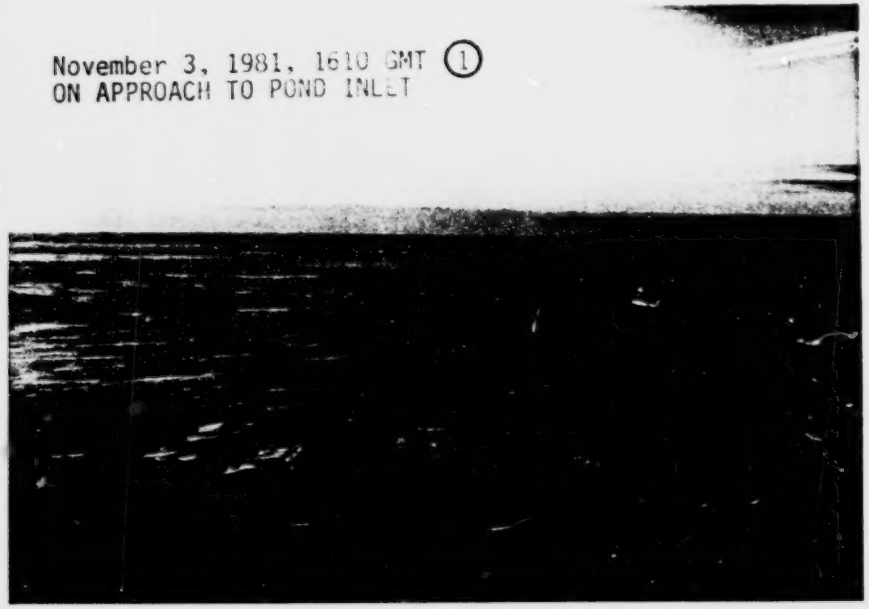
FIGURE 2.2

LAST TRIP OF 1981 SEASON

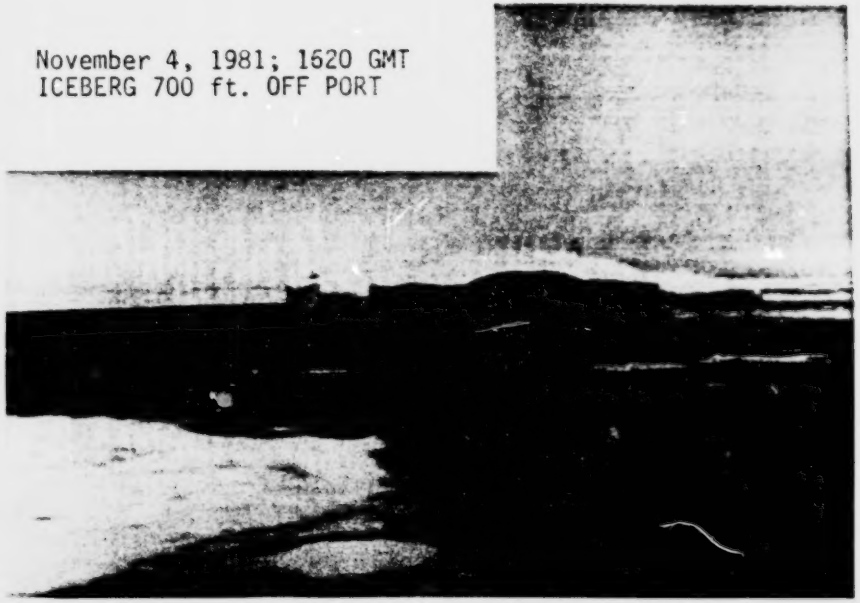
BAFFIN BAY


DEVON I.
LANCASTER SOUND
ICE TRIALS
1" = 60 ml.
BYLOT ISLAND
NAVY BOARD INLET
NANISIVIK
ADMIRALTY INLET
POND INLET
BAFFIN ISLAND
FOXE BASIN
BROUGHTON ISLAND →
① NOV 3/81 (IN BOUND TO NANISIVIK) 1/10 MYR, 9/10 COVERAGE OF IST YR.
② NOV 11/81, STRATHCONA SOUND (NANISIVIK)
③ NOV 12/81, (OUTBOUND) HEAVY MYR, BACKING AND RAMMING.
④ NOV. 13/81, (OUTBOUND) ICEBERG FIELD AT ENTRANCE TO NAVY BOARD INLET.
⑤ NOV. 14/81, (OUTBOUND) PACK ICE OFF POND INLET.

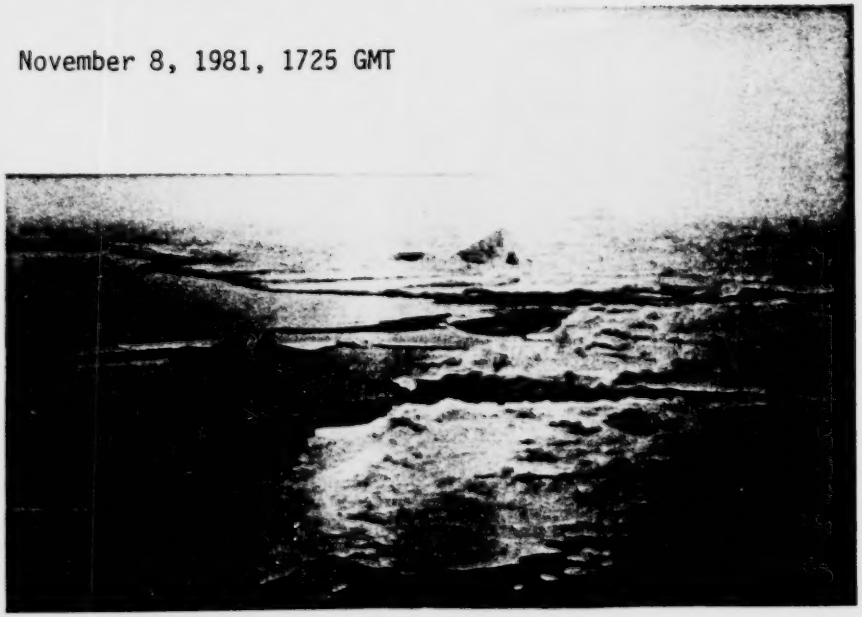
November 3, 1981, 1610 GMT (1)
ON APPROACH TO POND INLET



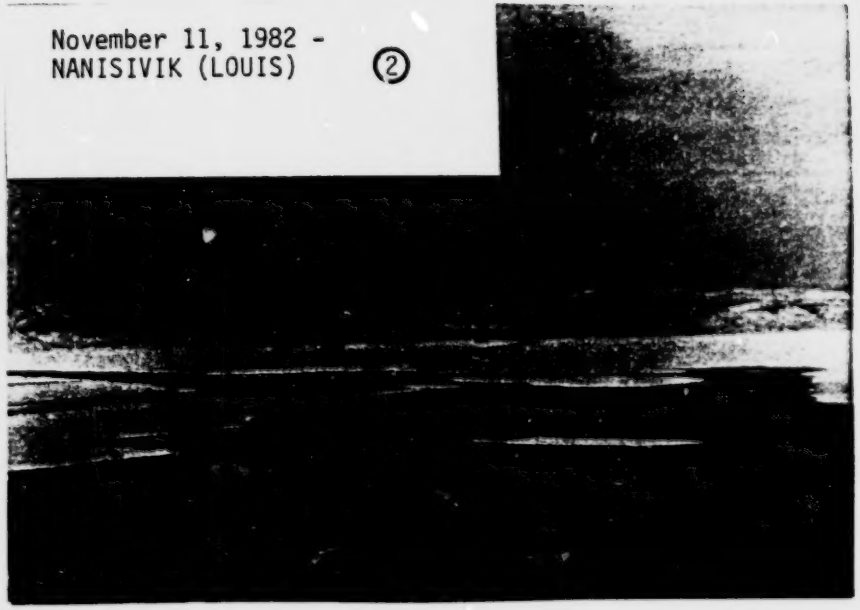
November 4, 1981; 1620 GMT
ICEBERG 700 ft. OFF PORT



November 8, 1981, 1725 GMT

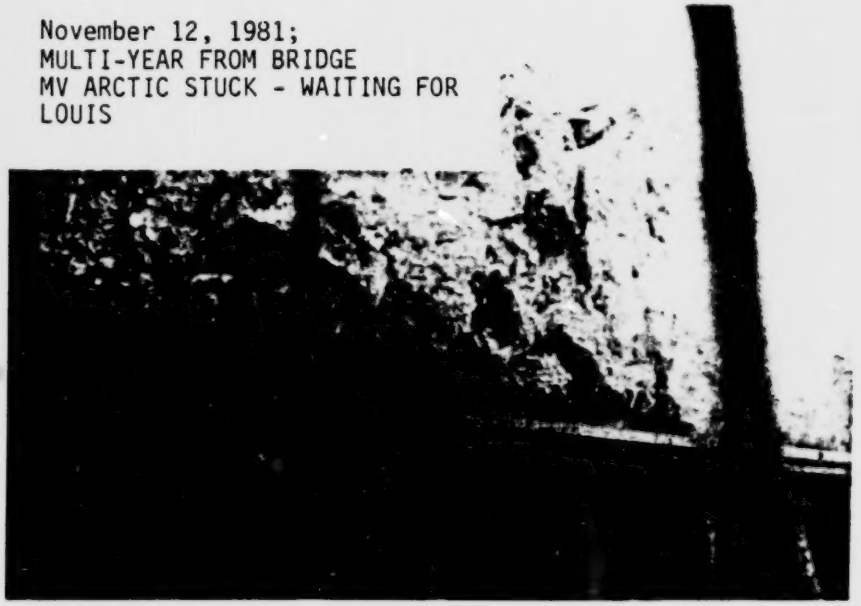


November 11, 1982 -
NANISIVIK (LOUIS) (2)

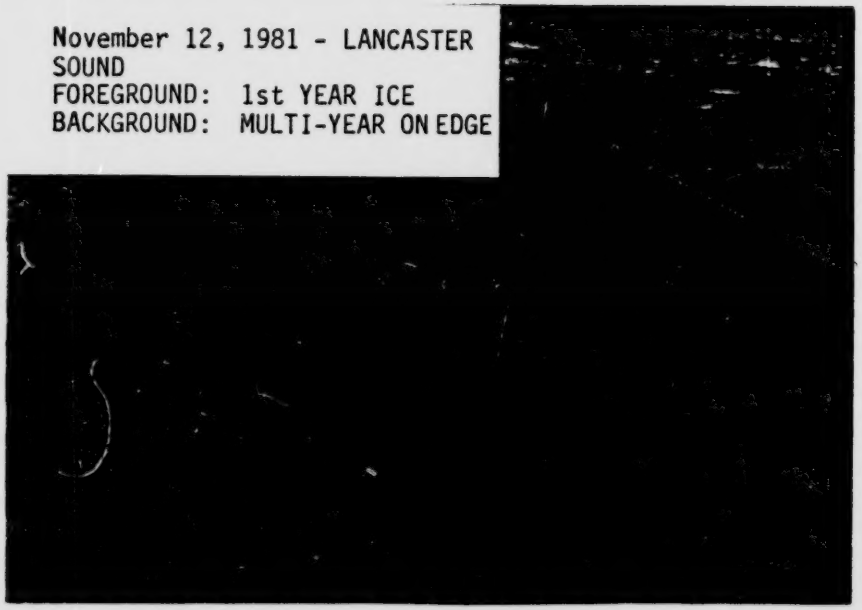


November 12, 1981 - 1st year
FROM OVER SIDE PORT, DRAFT -
34' LEVEL

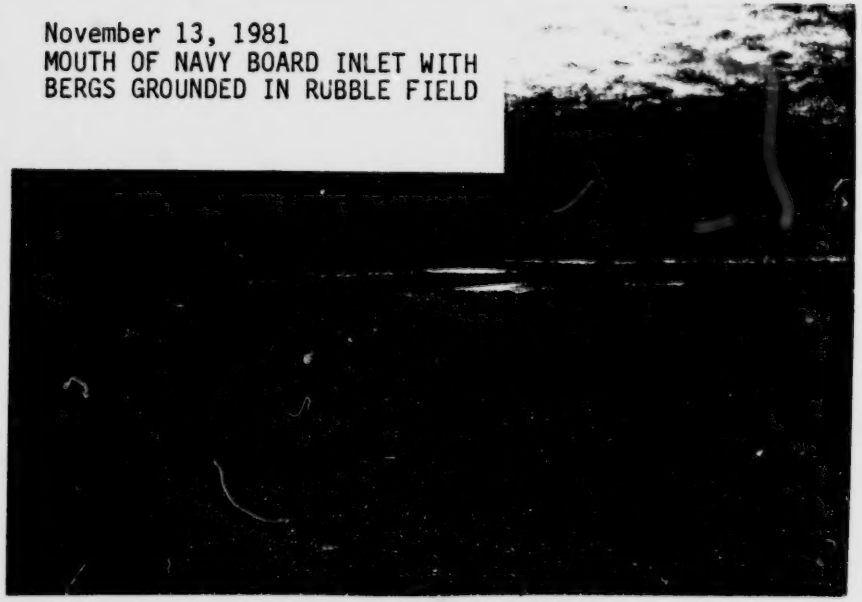
November 12, 1981;
MULTI-YEAR FROM BRIDGE
MV ARCTIC STUCK - WAITING FOR
LOUIS



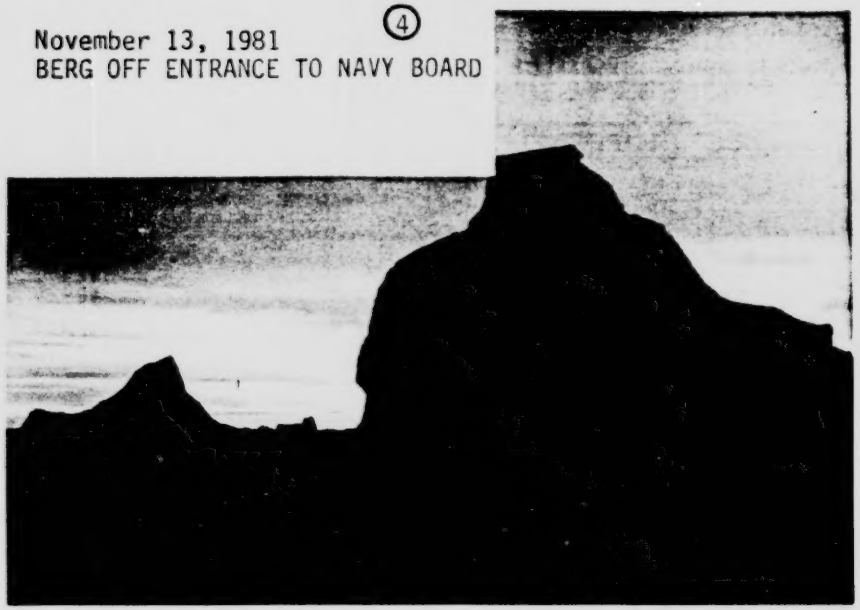
November 12, 1981 - LANCASTER
SOUND
FOREGROUND: 1st YEAR ICE
BACKGROUND: MULTI-YEAR ON EDGE



November 13, 1981
MOUTH OF NAVY BOARD INLET WITH
BERGS GROUNDED IN RUBBLE FIELD

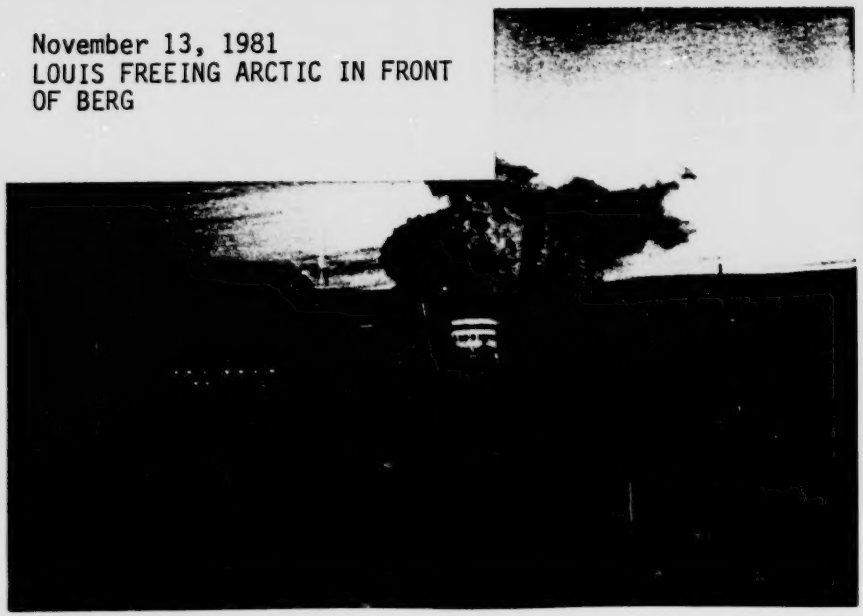


November 13, 1981 ④
BERG OFF ENTRANCE TO NAVY BOARD

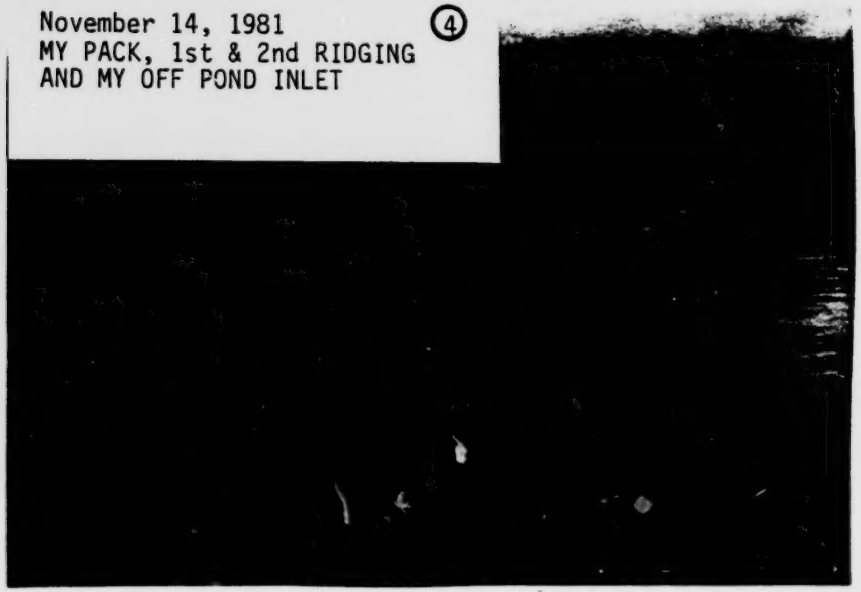


November 13, 1981
BERGS OFF NAVY BOARD - LOUIS
BREAKING OUT - ARCTIC IN
FRONT OF BERG.

November 13, 1981
LOUIS FREEING ARCTIC IN FRONT
OF BERG



November 14, 1981 ④
MY PACK, 1st & 2nd RIDGING
AND MY OFF POND INLET



3. DATA COLLECTION

3.1 System Description

The onboard data acquisition system has been described in detail on several occasions [2], [3] and so no description is repeated herein.

3.2 System Maintenance

The onboard operator was required to undertake onboard maintenance of the system in order to ensure its satisfactory operation, and to better understand the quality of the recorded data. The maintenance contractor was not aboard the ship during data collecting sequences. For reasons explained in Appendix B and summarized below, the level of maintenance effort was quite high as reflected in the separately logged maintenance hours reported in our monthly progress reports. Since the quality of the data is greatly affected by the system performance, the concerned reader should refer to the detailed maintenance log provided in Appendix B.

The actual reason for this high maintenance level should be discussed in order to improve on future designs of ship board data acquisition systems. The following conclusions are based on the experience of two ARCTEC CANADA LIMITED operators who performed extensive maintenance on the system in latter half of the 1981 operating season.

It was found that a significant number of integrated circuits failed in the 1981 season. These I.C.'s were CMOS chips used to decode addresses on the address bus and switch data onto the analog bus. CMOS chips are noted for their intolerance to static charge, transient voltages and excessive circuit loading. Typically CMOS circuit boards are protected from these effects with TT2 buffers (more tolerant technology) current limiters and, probably most effective, a "one-board" design. By installing all CMOS chips on one board and protecting all inputs and outputs with buffers the CMOS chips rarely see destructive voltages. Obviously this one-board approach is not always feasible, however by using proper design techniques (TTL buffers, etc.) CMOS can be implemented reliably.

On the MV ARCTIC some CMOS interfaces were buffered but many were not. With the continual insertion and re-insertion of these boards, in attempts to isolate bad gauges, transients occur which undoubtedly cause CMOS chips to fail. When one CMOS chip fails there is a cascading effect where one bad chip destroys other good chips.

A complication in the design of this system is the fact that there are hundreds of connectors connecting all these CMOS circuits together, strung out from bow to stern. Each one of these connectors can have anywhere from 10 to 30 pins creating a system with thousands of electrical contacts. Most of these contacts are in hostile surroundings. It was found that a lot of these contacts were wearing out as evident from contacts sticking to boards. On the other hand, boards were also found to leave their connectors for example while the vessel was in rough seas, again creating havoc with transient-sensitive CMOS circuits.

The lessons to be learned here are:

1) minimize the number of contacts in large systems such as this,
2) keep the boards away from hostile environments (i.e. forecastle),
3) minimize the use of CMOS circuits (or use TTL technology only),
4) use high quality connectors (gold contact, etc.) where ever connectors are necessary.

Problems with the main interface were noted in the latter half of the 1981 operating season and modifications made to it as a result (Appendix B.) Thermal problems reported in previous seasons were still encountered and it is unclear at this point why the system is temperature sensitive. Although cooling the room down to 65°F cures the problem it is felt the system should be operational a 75°F. To troubleshoot this problem a thorough understanding of the computer software as well as interface hardware would be necessary.

Gauge drift continued to be a problem as reported in previous years. The auto zero set having been inhibited, gauges must be rebalanced at the junction box using a voltmeter. This tedious operation was performed daily. As discussed later, gauge drift must be checked by inspection of the output of the monitor mode before data reduction.

The pan-tilt-zoom television system failed due to the hostile environment. The camera's environmental housing was vented to the outside causing excessive corrosion on all electronic parts. It is felt that it was a major design flaw to install a complex relay control system in the housing. It is also recommended that a sealed environmental housing be used.

3.3 System Operation

Forty-seven tapes were recorded during this late season. These are summarized in Table 3.1 along with descriptions of the prevailing ice conditions, approximate periods of data collection and sampling patterns. In addition the table indicates the length of period for which data reduction was performed. Ice thickness data is indicated where it was noted in the log. Additional estimates can be made by reference to the ship's position and ice charts, and to the video, although this latter had no date time code available with which to identify specific time periods. Figures 3.1 and 3.2 indicate the location at which tapes were recorded. Fifteen of these tapes were recorded in open water or in 'light' ice conditions. Although many of these were associated with system operational checks, this data may be of value in analyzing ice-free water performance. Of the remaining 32 tapes totalling 55 hours, 24 of these tapes were reduced statistically on the ship's last Atlantic crossing, including 13 discrete ramming cases. See Appendix C for a detailed account of the data collected.

TABLE 3.1

TAPE SUMMARY

	TAPE	NO. OF FILES	DATE-TIME (GMT)	TOTAL PERIOD	REDUCED PERIOD	PREDOM. SAMPLING PATTERN	DESCRIPTION
	1	4	9/6/81-1700	35 min.	35 min	A	Nanisivik Dock and light seas.
	2	7	9/7 & 8/81	66 min.	66 min	A	Light seas
	3	2	9/9/81	57 min.	57 min	A	Moderate ahead seas with roll
	4	16	9/17 & 18/81	43 min.	40 min	A	Maneuvering in Antwerp
	5	1	9/26/81	3 hrs.	3 hrs.	A	Maneuvering open water
	6	4	9/28	40 min.	40 min	A	Moderate to heavy seas
	7	4	10/5/81	30 min.	15 min	A	Docking in Nanisivik
	8	2	10/17/81	1 hr.	1 hr.	A	System tests in open water, no roll.
	9 & 10	Re-used	at later date				
	11	1	10/18/81	47 min.	-	B	Docking in Antwerp - system test.
	12	7	10/22-23/81	1 hr.	-	B	Leaving Antwerp - Tests with "LIPS"
	13	7	11/3/81	4 hrs	-	E	Young ice/1st yr.6-8"
	14	3	11/3/81	30 min.	-	B	10/10 coverage 1st year ice.
	15	4	11/4/81	2 hrs.	1 1/2 hrs	B,C	Open water & multi-year rams.12"1styr.48"2nd
	16	3	11/4/81	2 hrs.	2 hrs.	B,C	zero shift on 4 gauges 6/10 1st year, 3/10 multi-year.
	17	3	11/4-5/81	1 3/4 hrs.	-	B,C	6/10 1st year, 3/10 multi-year.
+	18	2	11/6/81	1 1/2 hrs.	-	B,C	Backing & ramming (Trials).
+	19	9	11/5-6/81	1 1/2 hrs.	1 1/4 hrs	I,B	Backing & ramming & continuous transit.1styr 2"snow,8"ice,myr 4-6'*
	20	3	11/6/81	2 hrs.	1 1/2 hrs	B,C	Continuous 1st year transit, loose pack.
	21	1	11/6/81	2 hrs.	-	C	Continous transit, loose pack.
+	22	5	11/7/81	1 1/2 hrs.	3/4 hrs	B	Backing & ramming, loose back, 2/10 MY-16' 1st yr-6-8"
							*zero shift on 3 channels

TABLE 3.1

TAPE SUMMARY

	TAPE	NO. OF FILES	DATE-TIME (GMT)	TOTAL PERIOD	REDUCED PERIOD	PREDOM. SAMPLING PATTERN	DESCRIPTION
+	23	1	11/7/81	20 min.	20 min	B	MY ram at high sampling rate.
+	24	3	11/7/81	1 1/2 hrs.	1 hr	B,F	Backing & ramming MY floe (20 ft). 1st yr 8-10"
+	25	7	11/7/81	1 1/2 hrs.	-	F,B	Backing & ramming continuous transit (lopse 1st year pack)
+	26	2	11/8/81	3 hrs.	3 hrs	C	(1.5" snow, 12" ice Backing & Ramming 2/10 MY, 1st yr 5" snow 9" ice
	27	1	11/8/81	1 hr.	1 hr	B	Continuous transit, 8/10 1st year
	28	1	11/8/81	1 hr.	1 hr	B	Continuous 1st yr transit, Admiralty Inlet.
	29	3	11/8/81	2 hrs	2 hrs	G,H	Doppler CALS in Adminalty Inlet, 1-2 ft 1st yr
	30	1	11/8/81	2 hrs	-	C	Maneuvering into Nanisivik
	31	1	11/11/81	3 hrs.	-	C	Leaving Nanisivik, 1st year ice.
	32	1	11/11/81	2 1/2 hrs.	2 min	C	9/10 coverage, 1st year with ridging. Zero shift on 2 gauges
	33	1	11/12/81	2 hrs.	2 hrs	C	1st year & MY ice, looking for LOUIS track
	34	1	11/12/81	2 1/2 hrs.	-	B,C	in LOUIS track but MY impacts.
	35	1	11/12/81	2 1/2 hrs.	-	B,C	In LOUIS track in MY ice
	36	2	11/12/81	2 hrs.	2 hrs	I	Backing & ramming in MY with milling.
	37	1	11/12/81	50 min.	15 min	I	Backing & ramming with heaving milling.
	38	1	11/12/81	1 1/2 hrs.	3/4 hr	B	Backing & ramming
	39	3	11/12/81	2 1/2 hrs.	2½ hr	B,C	Backing & ramming & continuous transit in LOUIS track.
	40	1	11/12/81	1 hr.	1 hr	B	Ramming in LOUIS track.

+ ICE TRIALS

TABLE 3.1

TAPE SUMMARY

TAPE	NO. OF FILES	DATE-TIME (GMT)	TOTAL PERIOD	REDUCED PERIOD	PREDOM. SAMPLING PATTERN	DESCRIPTION
41	1	11/12/81	2 hrs.	1 hr	G	Backing & ramming, ice milling.
42A	1	11/12/81	1 1/2 hrs.	1½ hr	G	Backing, ramming, milling.
42B	1	11/13/81	3 hrs.	Fatal run time errors	C	Backing & ramming.
43	3	11/13/81	3 hrs	2 hrs	C	Backing & ramming in front of iceberg.
44	2	11/13-14/81	2 hrs	-	B,C	Backing & ramming maneuvering in berg field and also backing & ramming in pack MY ice.
45	1	11/14/81	30 min.	30 min	B	1st&2nd yr 2-4 ft High rate, backing & ramming in pack ice.
46	1	11/15/81	3 1/2 hrs.	2 hrs	C	Following in LOUIS track.
47	5	11/15/81	2 1/2 hrs.	-	J,C	Ramming in 1/10 MY 1 mile visibility.
48*	2	11/15/81	1 hr.	-	D,C	Backing & ramming 1/10 MY.
49**	2	11/15/81	3 hrs.	-	C	LOUIS track, 1st year, 8/10 coverage. 6-8"thick

*Tape No. 9 re-used

**Tape No.10 re-used

3.4 Sampling Patterns

Selection of the sampling patterns is critical to the successful acquisition of quality data. Two major constraints affect this selection. The first is the availability of 'working' sensors. Sampling patterns often required to be altered due to gauge failure.

The second problem is associated with the effect of sampling pattern on sampling capacity. The sampling pattern chosen must not, of course, exceed the sampling capacity limit. This latter is reduced somewhat from the original 1765 samples per second, to around 1500 samples per second but is not known exactly. Due to the large number of sampling patterns theoretically possible, there is no way to anticipate patterns which will be rejected by the computer.

A total of 10 sampling patterns were employed, the details of these are given in Appendix C. In Table 3.2 we describe the patterns in a qualitative sense, and our objective in selecting them. In addition the patterns used for each tape are shown on the tape summary Table 3.1.

The sampling rates detailed in Appendix C were changed to meet the above objectives when it was apparent that ice conditions had changed. Due to the transient nature of ice milling, multi-year impacts and resulting ship motions it was not always possible to change patterns to accommodate new ice conditions and have these conditions remain compatible with the new pattern.

TABLE 3.2

SAMPLING PATTERN SELECTION

RATE PATTERN	PATTERN SUMMARY	OBJECTIVE
A	High Rate on 7 Strain Gauges	Used in Backing and Ramming Conditions - to capture time series strain data during impact
B	High Rate on 7 Different Strain Gauges	
C	Peak Mode on All Strain Gauges	Used in continuous transit lst yr ice - to collect general statistics
D	Time Series on 7 Different Gauges	As for A and B
E	Peak Mode on All Strain Gauges and Accelerometers	Ship Response in lst yr ice, 4/10 coverage
F	High Rate on Thrust and Torque	To capture ice milling incidents; unable to detect ice milling
G	High Rate on Accelerometers	To capture dynamic hull response during ramming with noticeable ship bending
H	Propulsion and Ship Speed Only	Doppler Log Calibrations
I	High Rate on 7 gauges and Torque and Thrust	Backing and Ramming with Milling
J	High Rate on Mid Ship Gauges	To capture hull bending during ramming (noticeable ship bending.

FIGURE 3.1
LOCATION AT WHICH TAPES WERE RECORDED
(Sept.6 - Oct.8)

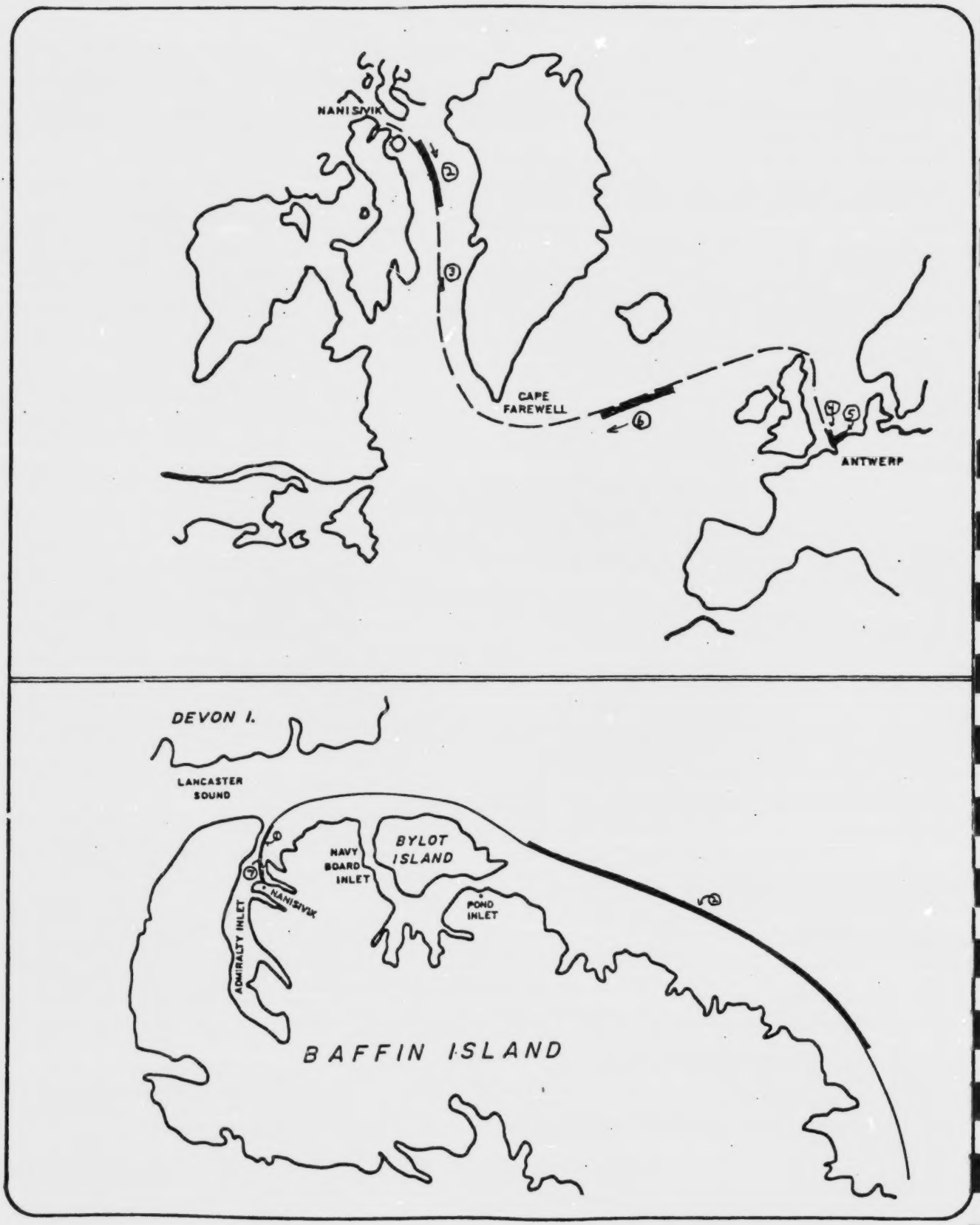
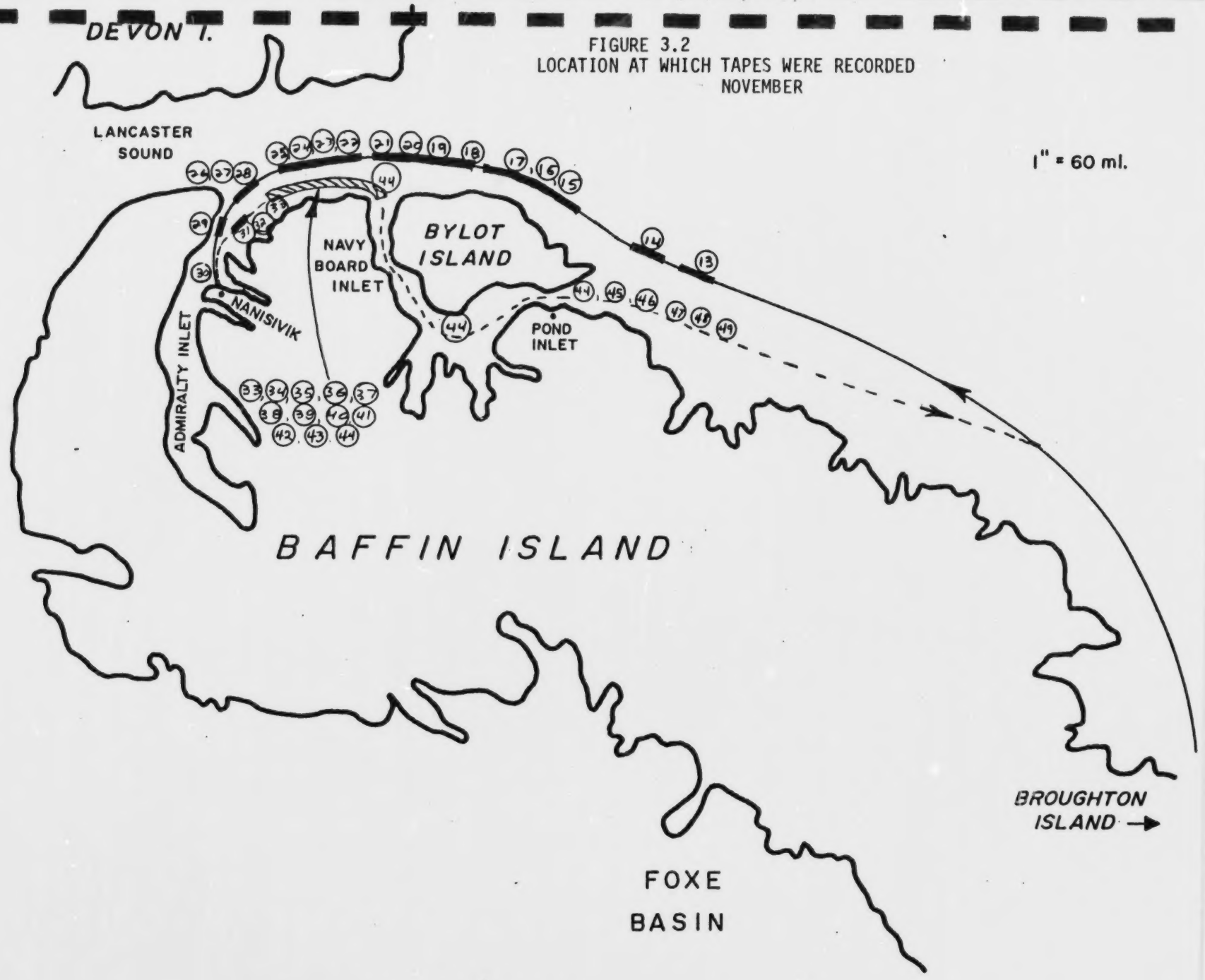


FIGURE 3.2
LOCATION AT WHICH TAPES WERE RECORDED
NOVEMBER



4. DATA ANALYSIS

4.1 Interpretation of Computer Analysis

Before presenting the results of the preliminary analysis it is necessary to discuss assumptions and techniques used. The system operations manuals[3] describe the computer data analysis program in detail. In summary the analysis program is run from the beginning of a data period to the end calculating the maximum, minimum, average, RMS and standard deviation of each channel in the sampled pattern. Typically, most channels were sampled in the peak mode and so during analysis one must be aware that minimum values are of limited usefulness. This is because the peak detectors are positive peak detectors and return the most positive value observed during the detection period, typically 1 second. Hence the minimum value observed during an analysis period is the least 'most positive' value during the return period (see Figure 4.1). One gets negative values in the minimum column because:

- a negative strain lasted longer than one second,
- the gauge acquired a negative zero shift.

The minimum strain column is therefore only useful in interpreting data sampled in the real time mode without peak detectors.

As discussed in Appendix B the strain gauges 'drifted' considerably (up to ± 200 mS) during one 24 hour period due to ship ballast conditions, thermal changes or faulty gauges.

To compensate for these drifts during data reduction the average strains from the computer analysis were assumed to be the gauge zero strain level. This is a fair assumption based on the relative level of activity and non-activity. Hence the maximum ice induced strain was interpreted as the maximum computed strain minus the average strain in the return period.

4.2 Analogue Data Recording

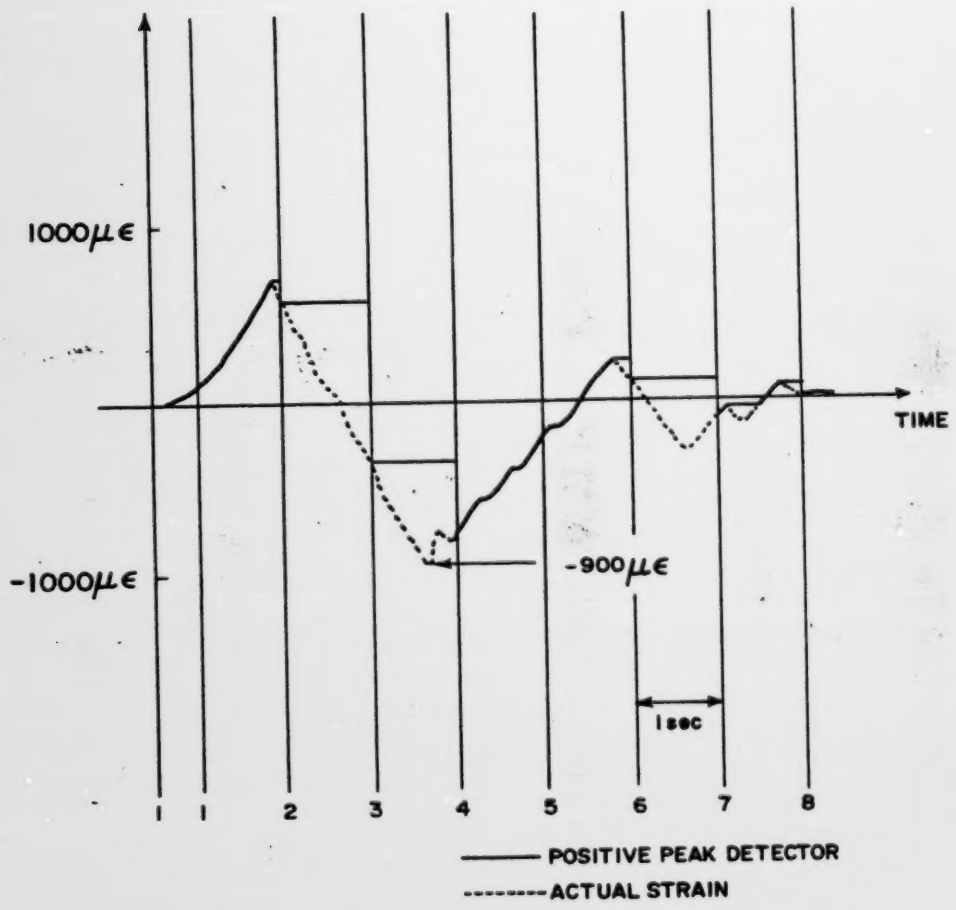
An analogue tape recorder was placed onboard for part of the season. This was primarily present for the evaluation of discrete impact data. The strain gauges to which this was connected were chosen based on:

(a) Study of the most active gauges from previous seasons.

(b) Objective of covering an area of the hull which was not being sampled at a high rate by the computer through filter channels.

FIG. 4.1

SCHEMATIC REPRESENTATION OF POSITIVE PEAK DETECTOR



TIME	STRAIN
1	200
2	700
3	600
4	-400
5	-200
6	250
7	120
8	75

← COMPUTER MAXIMUM : EQUALS : ACTUAL MAXIMUM (700μϵ)

← COMPUTER MINIMUM : DOES NOT EQUAL : ACTUAL MINIMUM (-900μϵ)

← COMPUTER MINIMUM : DOES NOT EQUAL : ACTUAL MINIMUM (-150μϵ)

(c) Available non defective gauges.

(d) Connection to a single junction box.

(e) Desire to compare analogue signals from adjacent web frame and main frame gauges.

Since the newly applied gauges at the shoulder (frames 178 and aft) were being sampled at high rates, an area further forward was selected to accommodate (b). To satisfy (e) the three gauges on web frame 184 were selected along with the main frame gauges on either side of this web. The gauges selected are shown in Figure 4.2.

The use of this recorder permits the presentation of typical time series strains, rise times, and limited comparison of analogue/digital data.

For further description of the analogue system see Appendix D.

4.3 Statistical Analysis

On completion of data collection every effort was made to perform statistical data reduction using the onboard computer before system shut down in Antwerp. Tape and file numbers selected for analysis were those judged by the operator to represent a wide spectrum of ship/ice interaction and to contain quality data, unaffected by zero shifts, system crashes, etc.

Table 4.0 identifies the tapes and files which were reduced onboard, classifying them by ship/environment conditions and stating the length of period covered.

As stated in the previous section, the statistical analysis routine provides the following data for each channel scanned:

a) maximum value

b) minimum value

c) average value

d) RMS value

e) standard deviation

Typical results for 2 file outputs are shown in Figures 4.3 and 4.4. However since a total of 24 tapes and 40 periods were reduced, these results are not tabulated but are available in a bound set of the computer printouts.

In addition, the program provides for up to 10 channels of time series output while reducing data in the monitor mode. The following channels were logged during this statistical analysis typically at a rate of once every 15 seconds real-time:

a) thrust (198)

b) fuel rack (199)

c) rudder response (200)

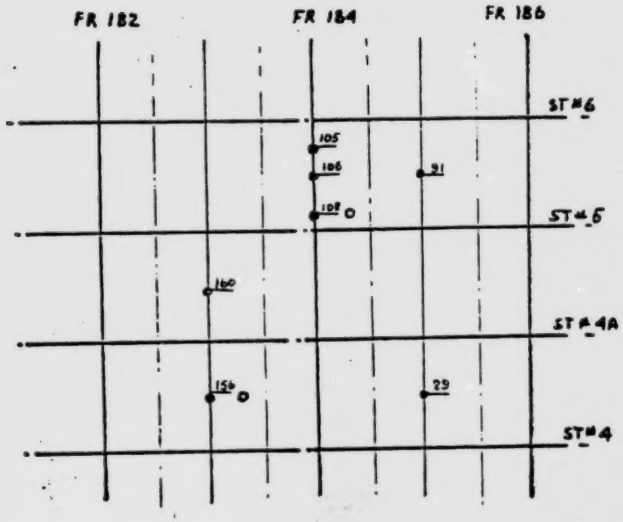


Figure 4.2 GAUGES SELECTED FOR ANALOGUE DATA RECORDING

Note: 124 not shown as it is not in this area and did not record.

TABLE 4.0

STATISTICALLY REDUCED DATA

CONDITIONS	REDUCED PERIOD [MIN]	TAPE #	FILE #
Open Water	35	1	00 to 03
	66	2	00 to 06
	57	3	00, 01
	46	4	00 to 15
	180	5	00
	40	6	00 to 03
	15	7	00 to 03
	60	8	00, 01
	Total # hrs = 8.2		
1st Yr Ice Continuous Transit	90	15	00
	60	27	01
	60	28	00
	120	29	01, 02
	120	46	00
	Total # hrs = 7.5		
Backing and Ramming in MY ice	75	19	01
	90	20	00, 01
	45	22	00
	20	23	00
	60	24	00, 01
	180	26	00, 01
	45	38	01
	120	43	00, 01
	30	45	00
	Total # hrs = 9.6		
Backing and Ramming MY ice, ice milling	120	36	00,01
	15	37	00
	60	41	00
	90	42A	00
	Total # hrs = 4.8		

FIGURE 4.3
TYPICAL STATISTICAL PRINT-OUT (TAPE 44-B) (TIME 2033 - 2216 GMT)

ADR	R/M	#REC	MIN	MAX	MEAN	RMS	SD
1	2 P	6177.	0.14	0.67	0.17	0.18	0.05 g
2	2 P	6177.	0.18	0.77	0.22	0.22	0.04 g
11	3 R	61765.	0.03	0.22	0.11	0.11	0.00 g
12	3 R	61765.	0.02	0.05	0.03	0.03	0.00 g
13	3 R	61765.	0.13	0.21	0.21	0.21	0.00 g
34	2 P	6177.	-62.23	124.45	-29.27	29.52	3.84 uS
35	2 P	6177.	-55.31	76.05	-20.43	20.72	3.43 uS
36	2 P	6177.	-118.07	243.75	-20.01	21.17	6.91 uS
38	2 P	6177.	-74.22	-7.42	-45.01	45.19	4.05 uS
39	2 P	6177.	-57.13	0.00	-45.53	45.79	4.84 uS
40	2 P	6177.	-57.13	-11.43	-44.69	44.96	4.99 uS
41	2 P	6177.	-38.28	7.66	-24.40	24.81	4.53 uS
42	2 P	6177.	-195.23	-103.36	-138.13	139.38	18.62 uS
43	2 P	6177.	-62.23	162.48	-34.98	35.52	6.20 uS
45	2 P	6177.	-53.61	525.41	-38.97	40.49	11.01 uS
49	2 P	6177.	-25.02	0.00	-16.44	17.08	4.65 uS
50	2 P	6177.	-7.15	160.84	7.40	10.33	7.21 uS
51	2 P	6177.	-26.66	45.70	-16.16	16.82	4.64 uS
52	2 P	6177.	-99.02	60.94	-32.32	32.88	6.05 uS
53	2 P	6177.	-82.21	14.30	-45.09	45.28	4.14 uS
54	2 P	6177.	-72.36	76.17	-21.43	22.41	6.55 uS
55	2 P	6177.	-91.41	95.22	-49.71	50.06	5.90 uS
56	2 P	6177.	-95.22	-53.32	-66.34	66.55	5.27 uS
57	2 P	6177.	-103.65	-67.91	-81.89	82.16	5.68 uS
58	2 P	6177.	-39.32	185.86	-22.66	24.52	9.37 uS
59	2 P	6177.	-39.32	64.34	-27.27	27.61	4.30 uS
63	2 P	6177.	-95.22	11.43	-62.52	62.81	6.07 uS
64	2 P	6177.	-76.17	186.62	-17.02	17.84	5.36 uS
65	2 P	6177.	-118.07	11.43	-50.58	50.76	4.34 uS
66	2 P	6177.	-89.36	-10.72	-50.70	50.82	3.56 uS
67	2 P	6177.	-42.89	35.74	-4.21	6.04	4.34 uS
70	2 P	6177.	14.30	171.56	20.31	21.08	5.62 uS
72	2 P	6177.	-30.47	38.09	-18.57	19.16	4.70 uS
73	2 P	6177.	-79.98	57.13	-35.93	36.18	4.28 uS
74	2 P	6177.	-64.75	171.39	-18.76	19.83	6.43 uS
75	2 P	6177.	-96.50	107.23	-44.41	44.76	5.59 uS
76	2 P	6177.	-58.12	50.86	-19.33	19.71	3.88 uS
79	2 P	6177.	-72.36	-34.28	-45.06	45.22	3.81 uS
80	2 P	6177.	-17.87	21.48	-4.69	5.89	3.56 uS
81	2 P	6177.	-38.09	125.68	-28.77	29.01	3.76 uS
86	2 P	6177.	-57.19	189.43	-32.70	33.53	7.38 uS
89	2 P	6177.	-50.04	325.25	-30.02	31.69	10.15 uS
91	2 P	6177.	-75.06	39.32	-49.28	49.81	7.27 uS
93	2 P	6177.	-57.13	87.60	-32.38	32.70	4.59 uS
94	2 P	6177.	-53.32	213.28	-41.30	41.86	6.93 uS
95	2 P	6177.	-35.74	28.59	-25.16	25.19	1.36 uS
97	2 P	6177.	-64.75	38.09	-34.80	35.14	4.92 uS
98	2 P	6177.	-19.04	274.22	-4.28	8.13	6.91 uS
101	2 P	6177.	-53.32	346.58	-27.18	28.01	6.74 uS
102	2 P	6177.	0.00	91.41	9.84	11.10	5.14 uS
103	2 P	6177.	-22.85	72.36	-13.35	13.84	3.65 uS

FIGURE 4.3
continued

104	2	P	6177.	-3.81	114.26	10.10	10.52	2.94 uS
105	2	P	6177.	-35.74	92.93	-22.23	22.42	2.94 uS
106	2	P	6177.	-111.02	-19.14	-47.25	48.12	9.15 uS
108	2	P	6177.	-34.45	-7.66	-30.20	30.28	2.28 uS
110	2	P	6177.	-91.41	53.32	-48.54	48.98	6.61 uS
111	2	P	6177.	-64.75	57.13	-38.36	38.61	4.38 uS
112	2	P	6177.	-22.85	114.26	-8.38	10.30	5.99 uS
113	2	P	6177.	-60.94	60.94	-24.75	25.01	3.54 uS
116	2	P	6177.	-34.28	190.43	-14.56	17.85	10.32 uS
117	2	P	6177.	-41.89	72.36	-14.83	17.09	8.49 uS
118	2	P	6177.	-57.42	53.59	-22.84	23.34	4.80 uS
120	2	P	6177.	-64.34	210.88	-33.06	33.60	5.96 uS
126	2	P	6177.	-53.32	285.65	-25.17	26.16	7.15 uS
128	2	P	6177.	-53.61	285.94	-30.43	31.15	6.62 uS
130	2	P	6177.	-31.11	193.59	-17.47	18.29	5.40 uS
131	2	P	6177.	-32.17	235.90	-0.94	5.47	5.39 uS
132	2	P	6177.	-60.76	153.69	-43.71	44.04	5.42 uS
133	2	P	6177.	-15.31	61.25	1.54	3.79	3.46 uS
134	2	P	6177.	-26.80	111.02	-13.21	13.73	3.75 uS
135	2	P	6177.	-80.39	111.02	-39.06	44.62	21.57 uS
136	2	P	6177.	-72.73	160.78	-49.81	50.61	8.97 uS
137	2	P	6177.	-34.45	99.53	-23.59	24.13	5.08 uS
138	2	P	6177.	-49.77	91.87	-4.01	15.22	14.68 uS
139	2	P	6177.	-80.39	145.47	-58.24	58.92	8.97 uS
140	2	P	6177.	-88.05	405.78	-44.46	45.69	10.55 uS
141	2	P	6177.	-30.47	15.23	-12.88	13.14	2.59 uS
142	2	P	6177.	-41.89	285.65	-24.17	25.51	8.16 uS
145	2	P	6177.	-72.73	306.25	-40.34	41.18	8.25 uS
146	2	P	6177.	-95.22	-7.62	-82.89	83.04	4.94 uS
147	2	P	6177.	-41.89	220.90	-29.08	29.50	4.92 uS
148	2	P	6177.	-68.55	228.52	-45.81	47.08	10.87 uS
151	2	P	6177.	-38.09	137.11	-31.01	31.76	6.86 uS
153	2	P	6177.	-72.73	436.40	-30.72	32.40	10.29 uS
155	2	P	6177.	-38.03	86.43	-23.10	23.34	3.36 uS
156	2	P	6177.	-118.07	319.92	-81.17	81.77	9.89 uS
157	2	P	6177.	-38.09	102.83	-19.90	20.74	5.82 uS
160	2	P	6177.	-67.91	353.85	-39.50	40.46	8.75 uS
161	2	P	6177.	-45.70	60.94	-30.59	30.75	3.09 uS
162	2	P	6177.	-45.70	60.94	-32.75	32.93	3.40 uS
163	2	P	6177.	-46.46	14.30	-29.76	29.98	3.63 uS
166	2	P	6177.	-45.70	738.87	-30.11	31.75	10.08 uS
167	2	P	6177.	-83.79	190.43	-51.77	53.00	4.91 uS
169	2	P	6177.	-68.55	167.58	-42.59	42.85	4.71 uS
170	2	P	6177.	-49.51	255.18	-42.70	43.36	7.49 uS
174	2	P	6177.	-229.69	-26.80	-135.43	136.57	17.66 uS
176	2	P	6177.	0.62	0.89	0.73	0.73	0.02 V
177	2	P	6177.	-0.05	0.23	0.07	0.07	0.02 V
178	2	P	6177.	-0.38	-0.03	-0.22	0.22	0.02 V
179	2	P	6177.	-0.58	-0.28	-0.46	0.46	0.02 V
196	3	R	61765.	0.05	0.07	0.06	0.06	0.01 V
198	3	R	61765.	-97.50	106.20	30.11	60.36	52.31 tonnes
199	2	R	6177.	-9.97	70.81	49.94	51.74	13.51 %
200	2	R	6177.	-36.48	34.69	-4.04	18.30	17.85 deg
201	3	R	61765.	-14.43	17.16	6.15	13.93	12.51 deg

FIGURE 4.3
continued

```
202 2 R      6177.    16.87    17.20    17.03    17.03    0.08 MPa
203 2 R      6177.     6.79     6.83     6.81     6.81    0.00 MPa
208 3 R     61765.    29.93   754.82   428.10   457.34  160.90 KNm
209 3 R     61765.    -2.27     4.90    -0.10     0.59    0.58 V
211 2 R      6177.    -1.97     3.09    -1.20     1.30    0.50 V
212 2 P      6177.     0.09     0.65     0.33     0.34    0.07 s
213 2 P      6177.     0.25     1.46     0.82     0.83    0.16 s
214 2 P      6177.     0.17     0.62     0.39     0.39    0.06 s
215 3 R     61765.    -0.05    -0.02    -0.03     0.03    0.00 s
216 3 R     61765.    -0.06     0.02    -0.02     0.02    0.00 s
217 3 R     61765.    -0.06     0.10     0.04     0.04    0.01 s
233 2 R      6177.    85.41   124.41   101.48   101.60    4.84 knots
234 2 R      6177.   200.36    74.84   139.79   142.01   24.99
236 2 R      6177.     0.00    17.11     1.36     2.13    1.64 knots
RUNTIME ERROR 7 AT LOC. 054514, CALLED FROM LOC. 040763
RUNTIME ERROR 7 AT LOC. 054514, CALLED FROM LOC. 040763
238 2 R      6177.   -90.00   -90.00   137.63   138.30   13.66
239 3 R     61765.    -1.05     0.31    -0.31     0.36    0.19 V
240 3 R     61765.   -10.00     1.48    -3.48     5.53    4.29 V
244 2 R      6177.     0.00    17.24     1.77     4.58    4.23 deg
245 2 R      6177.   -35.37    34.75    -2.41    17.30   17.13 deg
255 2 R      6177.     9.63     9.71     9.68     9.68   17.13 V
1 NEW OUTPUT
2 NEW SEARCH
3 NEW FILE
4 NEW TAPE
: 3

FILE START 81Y 11M 14D 22H 17M 17S
 943.0 SAMPLES/SEC
1 TO START HERE
2 TO SEARCH FOR START TIME
3 TO SEARCH FOR ALARMS
4 TO MODIFY ALARMS
: 1
END DATE (Y OR N)? N
1 MONITORING
2 DUMP
: 2
TYPE? N
ESC
TAPE PROCESSED TILL: 81Y 11M 14D 22H 17M 17S
     1 TAPE RECORDS READ.
TYPE STATISTICS? NO
1 NEW OUTPUT
2 NEW SEARCH
3 NEW FILE
4 NEW TAPE
: 3
EOT
MOUNT TAPE FOR READING, TYPE UNIT # (0 OR 1): 1
TYPE FILE ## OR 00: 00.

FILE START 81Y 11M 14D 22H 18M  6S
 943.0 SAMPLES/SEC
1 TO START HERE
2 TO SEARCH FOR START TIME
3 TO SEARCH FOR ALARMS
```

FIGURE 4.4
TYPICAL STATISTICAL PRINT-OUT (TAPE 44-G)(TIME 2218-2226 GMT)

ADR	R/M	#REC	MIN	MAX	MEAN	RMS	SD
1	2 P	530.	0.14	1.53	0.23	0.26	0.11 s
2	2 P	530.	0.18	1.01	0.28	0.29	0.09 s
11	3 R	5295.	0.03	0.17	0.11	0.11	0.00 s
12	3 R	5295.	0.02	0.03	0.03	0.03	0.00 s
13	3 R	5295.	0.21	0.21	0.21	0.21	0.00 s
34	2 P	530.	-34.57	-10.37	-30.26	30.35	2.42 uS
35	2 P	530.	-27.66	-3.46	-20.39	20.50	2.09 uS
36	2 P	530.	-34.28	15.23	-21.16	21.49	3.78 uS
38	2 P	530.	-48.24	-18.55	-42.26	42.42	3.71 uS
39	2 P	530.	-49.51	-26.66	-44.04	44.13	2.78 uS
40	2 P	530.	-49.51	-26.66	-45.26	45.32	2.46 uS
41	2 P	530.	-34.45	-11.48	-30.92	31.01	2.40 uS
42	2 P	530.	-179.92	-111.02	-137.05	137.78	14.18 uS
43	2 P	530.	-41.48	-17.29	-36.78	36.87	2.55 uS
45	2 P	530.	-46.46	32.17	-36.18	37.17	8.51 uS
49	2 P	530.	-25.02	-7.15	-24.73	24.77	1.44 uS
50	2 P	530.	3.57	60.76	14.84	16.79	7.86 uS
51	2 P	530.	-30.47	7.62	-24.02	24.33	3.91 uS
52	2 P	530.	-41.89	30.47	-30.40	30.64	3.82 uS
53	2 P	530.	-46.46	-17.87	-41.59	41.69	2.95 uS
54	2 P	530.	-30.47	228.52	-19.66	23.93	13.66 uS
55	2 P	530.	-57.13	15.23	-47.70	47.94	4.77 uS
56	2 P	530.	-72.36	-60.94	-64.77	64.78	0.74 uS
57	2 P	530.	-92.93	-82.21	-87.02	87.04	1.79 uS
58	2 P	530.	-28.59	1011.50	-15.58	48.07	45.52 uS
59	2 P	530.	-42.89	-7.15	-38.38	38.51	3.15 uS
63	2 P	530.	-72.36	243.75	-56.91	58.51	13.62 uS
64	2 P	530.	-26.66	-11.43	-19.07	19.08	0.70 uS
65	2 P	530.	-57.13	38.09	-49.20	49.39	4.34 uS
66	2 P	530.	-53.61	-17.87	-48.86	48.95	3.04 uS
67	2 P	530.	-10.72	14.30	-2.46	3.65	2.70 uS
70	2 P	530.	17.87	882.83	24.48	47.11	40.29 uS
72	2 P	530.	-30.47	68.55	-23.73	24.28	5.16 uS
73	2 P	530.	-41.89	110.45	-35.73	36.45	7.22 uS
74	2 P	530.	-41.89	15.23	-20.43	20.93	4.56 uS
75	2 P	530.	-53.61	0.00	-40.85	41.02	3.74 uS
76	2 P	530.	-21.80	10.90	-16.77	17.11	3.42 uS
79	2 P	530.	-49.51	-38.09	-45.25	45.27	1.32 uS
80	2 P	530.	-7.15	232.32	-1.93	10.69	10.52 uS
81	2 P	530.	-34.28	57.13	-28.79	29.29	5.37 uS
83	5 R	52950.	-46.46	3.57	-21.77	21.84	1.82 uS
86	2 P	530.	-39.32	200.16	-27.16	29.95	12.53 uS
89	2 P	530.	-35.74	-3.57	-31.73	31.81	2.25 uS
91	2 P	530.	-46.46	0.00	-37.88	38.09	3.97 uS
93	2 P	530.	-41.89	-3.81	-34.48	34.56	2.41 uS
94	2 P	530.	-49.51	-19.04	-41.74	41.79	2.04 uS
95	2 P	530.	-25.02	3.57	-24.77	24.85	1.96 uS
97	2 P	530.	-38.09	57.13	-28.80	30.46	9.92 uS
98	2 P	530.	-11.43	22.85	-3.77	4.39	2.25 uS
101	2 P	530.	-41.89	-19.04	-27.59	27.67	2.00 uS
102	2 P	530.	3.81	361.82	15.29	25.17	20.02 uS
103	2 P	530.	-19.04	179.00	-16.02	18.87	9.98 uS
104	2 P	530.	-3.81	19.04	11.14	11.24	1.49 uS
105	2 P	530.	-25.02	-7.15	-23.15	23.37	3.19 uS
106	2 P	530.	-53.59	-26.80	-38.06	38.18	3.02 uS

FIGURE 4.4 continued

108 2 P	530.	-34.45	-11.48	-33.43	33.50	2.06 uS
110 2 P	530.	-57.13	49.51	-44.65	45.49	9.75 uS
111 2 P	530.	-41.89	-11.43	-35.99	36.09	2.56 uS
112 2 P	530.	-19.04	281.84	-0.68	16.87	16.88 uS
113 2 P	530.	-26.66	11.43	-20.88	21.16	3.40 uS
116 2 P	530.	-22.85	83.79	-7.49	13.68	11.46 uS
117 2 P	530.	-38.09	0.00	-24.78	25.05	3.66 uS
118 2 P	530.	-26.80	22.97	-19.64	19.71	5.07 uS
120 2 P	530.	-39.32	343.12	-31.75	35.75	16.45 uS
123 5 R	52950.	-41.89	293.26	-14.51	17.73	10.18 uS
124 5 P	52950.	-95.22	140.93	-49.16	49.41	4.96 uS
125 5 R	52950.	-57.13	0.00	-11.39	11.59	2.10 uS
126 2 P	530.	-26.66	293.26	-18.30	22.84	13.68 uS
128 2 P	530.	-35.24	35.24	-23.82	24.97	2.48 uS
130 2 P	530.	-20.74	17.29	-16.89	17.04	2.27 uS
131 2 P	530.	-3.57	28.59	-1.30	2.97	2.68 uS
132 2 P	530.	-57.19	28.59	-47.32	47.92	2.57 uS
133 2 P	530.	0.00	42.11	2.41	3.92	3.09 uS
134 2 P	530.	-26.80	38.28	-13.75	14.36	4.18 uS
135 2 P	530.	-57.42	-19.14	-47.44	47.77	5.67 uS
136 2 P	530.	-65.08	22.97	-56.97	57.14	4.41 uS
137 2 P	530.	-26.80	65.08	-18.04	19.50	7.43 uS
138 2 P	530.	-53.59	11.48	-33.89	33.35	5.53 uS
139 2 P	530.	-80.39	149.30	-57.50	61.01	20.40 uS
140 2 P	530.	-57.42	26.80	-47.49	48.63	10.46 uS
141 2 P	530.	-60.94	3.81	-13.07	13.63	3.86 uS
142 2 P	530.	-26.66	49.51	-24.38	24.96	5.36 uS
145 2 P	530.	-42.11	38.28	-30.97	32.35	9.34 uS
146 2 P	530.	-91.41	-53.32	-86.38	86.43	2.91 uS
147 2 P	530.	-34.28	-7.62	-29.30	29.39	2.21 uS
148 2 P	530.	-72.36	19.04	-59.73	60.73	10.99 uS
150 5 R	52950.	-45.70	0.00	-30.68	30.73	1.79 uS
151 2 P	530.	-34.28	114.26	-25.78	30.70	16.70 uS
153 2 P	530.	-34.45	168.44	-22.61	26.30	13.44 uS
155 2 P	530.	-24.20	55.31	-22.80	23.21	4.36 uS
156 2 P	530.	-91.41	-38.09	-86.93	86.98	2.84 uS
157 2 P	530.	-34.28	125.68	-12.35	21.62	17.76 uS
160 2 P	530.	-42.89	210.88	-32.76	35.61	17.97 uS
161 2 P	530.	-34.28	41.89	-29.89	30.13	3.73 uS
162 2 P	530.	-57.13	114.26	-34.03	35.26	9.26 uS
163 2 P	530.	-28.59	7.15	-25.09	25.22	2.49 uS
164 5 R	52950.	-82.21	0.00	-69.60	69.68	3.40 uS
166 2 P	530.	-41.89	60.94	-30.03	30.35	4.37 uS
167 2 P	530.	-68.55	-26.65	-53.51	53.56	2.36 uS
169 2 P	530.	-57.13	19.04	-44.39	44.54	3.71 uS
170 2 P	530.	-53.32	3.81	-45.23	45.33	2.97 uS
171 5 P	52950.	-45.94	3.83	-25.05	25.16	2.28 uS
174 2 P	530.	-333.04	-103.36	-157.64	168.79	60.39 uS
176 2 P	530.	0.72	0.99	0.74	0.74	0.01 U
177 2 P	530.	0.03	0.19	0.05	0.05	0.01 U
178 2 P	530.	-0.26	-0.07	-0.23	0.23	0.02 U
179 2 P	530.	-0.48	-0.32	-0.44	0.45	0.01 U
196 3 P	5295.	0.05	0.07	0.06	0.06	0.01 U

FIGURE 4.4 continued

198 3 R	5295.	-56.71	118.38	37.92	58.19	44.15	tonnes
199 2 R	530.	-2.49	65.30	46.94	48.83	13.46	%
200 2 R	530.	-36.25	34.69	-7.74	26.13	24.98	deg
201 3 R	5295.	-12.24	16.12	8.65	13.41	10.25	deg
202 2 R	530.	16.90	17.17	17.04	17.04	0.07	MPa
203 2 R	530.	6.81	6.81	6.81	6.81	0.00	MPa
208 3 R	5295.	38.95	817.93	408.97	443.80	172.36	KNm
209 3 R	5295.	-2.23	4.78	-0.09	0.60	0.59	V
211 2 R	530.	-1.74	4.21	-0.85	1.46	1.19	V
212 2 P	530.	0.09	0.71	0.31	0.32	0.08	g
213 2 P	530.	0.22	1.34	0.76	0.78	0.16	g
214 2 P	530.	0.13	0.65	0.35	0.36	0.07	g
215 3 R	5295.	-0.04	-0.02	-0.03	0.03	0.00	g
216 3 R	5295.	-0.05	0.00	-0.02	0.02	0.01	g
217 3 R	5295.	-0.03	0.10	0.03	0.03	0.01	g
233 2 R	530.	92.79	116.92	102.12	102.19	3.94	knots
234 2 R	530.	147.27	93.83	125.29	125.70	10.09	knots
236 2 R	530.	1.47	14.01	3.97	4.27	1.58	knots
RUNTIME ERROR 7 AT LOC. 054514. CALLED FROM LOC. 040763							
RUNTIME ERROR 7 AT LOC. 054514. CALLED FROM LOC. 040763							
238 2 R	530.	-90.00	-90.00	144.69	144.78	4.85	knots
239 3 R	5295.	-0.73	0.09	-0.32	0.36	0.16	V
240 3 R	5295.	-10.00	1.54	-0.40	2.07	2.03	V
244 2 R	530.	0.08	0.08	0.08	0.08	0.00	deg
245 2 R	530.	-34.82	34.75	-5.06	25.26	24.77	deg
255 2 R	530.	9.69	9.71	9.69	9.69	24.77	V
CONTINUE?							

d) propeller response (201)

e) torque (208)

f) RPM analogue (211)

g) ship speed (236).

Fourteen of the 40 periods analyzed by computer have been chosen here for further analysis as the were judged to include interesting periods of ice encounter. This was also the maximum number considered possible within the time and budget restraint. For each of these fourteen cases the following calculations ere performed:

1) All active gauge maximum values corrected for offset by subtracting the gauge average value as described previously.

2) All frame and plate gauges reading over 100 μS identified and plotted graphically on pictorial representations of hull profile and gauge locations. The 100 μS threshold was selected based on analysis of the 'noise' level in the system.

From these initial results it was decided that the following parameters would be useful in assessing ship performance:

a) FR > 100 μS: The number of frame gauge reading greater than 100 μS during the statistical collection period.

b) FR SUM : The sum of the frame strain maximums

c) FR AVE : The average of the frame strain maximums

d) FR MAX : The maximum frame strain

e) PL > 100 μS: The number of plate gauges greater than 100 μS.

f) PL MAX : The maximum plate strains

g) VEL AVE : The average ship speed (knots)

h) T AVE : The average thrust in metric tonnes

i) VEL MAX : The maximum ship speed.

These parameters are indirect indicators of load area, magnitude and impact pressure which are a few of the main factors of interest to the designers of structure against ice loads. Others are of course the load rise time and duration.

Although the system as fitted cannot provide direct values for these factors due to gauge distribution and lack of suitable calibration, the following explains how the parameter chosen can be assumed relative to the desired factors.

The two parameters FR > 100 μS and PL > 100 μS (especially the latter) are an approximate indication of the area of the hull over which the ice was acting during the statistical period. They are thus a measure of activity intensity only.

Since the normal conversion of measured structural strains to ice loads is via an algorithm in which ice load is expressed as a function of sums, averages or products of combinations of strains, the parameters FR SUM, FR AVE and FR MAX are an approximate indication of the magnitude of the maximum load experienced during the statistical period. Note that these parameters are intended as load indicators only and are by no means suitable for calculating load magnitudes, since load locations, ship structure and finite element analysis have not been considered here. From past experience [4] [5] algorithms for frame loading have taken these algebraic forms once the scaling factors have been found from finite element analysis and full scale calibration. The report in which this material was presented [6] was examined in detail, but insufficient information is available there from which to deduce loads.

The parameter PL MAX will provide information on the degree of local loading and hence may be considered an indication of ice pressure.

The ship velocity (average and maximum) is important for continuous and ramming analysis along with the ship's average thrust.

The values of these parameters for the cases examined are shown in Table 4.1.

These results were compared graphically after the 14 statistical periods were divided into two categories: backing and ramming, and continuous transit. Table 4.2 describes each of the 14 periods in terms of ship maneuvers and ice conditions. Table 4.3 summarizes the results of the plots by indicating which plots produced meaningful correlations and which produced no correlations. Typical plots are shown in Figures 4.5 and 4.6 , and all are reproduced in Appendix E.

Tape 26-B was a mixture of ship activities and so it was used in both the backing and ramming and continuous transit cases.

Summarizing from Table 4.3 and Appendix E the following observations may be made:

(a) The area of impact activity (as indicated by PL > 100 μS) has a linear relationship with the load levels as indicated by the values of plate and frame maximum strains, in both continuous transit and backing and ramming.

(b) In continuous transit the load levels as indicated by the values of the sum and average of frame maximums, and the maximum frame strains correlate well with ship average velocity as does the area or extent of impact activity. As might be expected, no such correlation is evident from the backing and ramming data. Nor was there correlation of any parameters with the maximum velocity recorded during backing and ramming.

TABLE 4.1

RESULTS OF STATISTICAL ANALYSIS FOR SELECTED CASES

TAPE OBSERVATION NO TAPE NO.	CT#1 16-C	BR#1 19E-1	CT#2 20-A	CT#3 20-B	BR#2 22-A	BR#3/CT#4 26-A	BR#4 26-B	CT#5 27-B	CT#6 28-A	CT#7 28-B	CT#8 32-A	BR#5 36-A	BR#6 36-B	BR#7 38-B
NO. OF FRAME GAUGES OVER 100 μS (#FR > 100 μS)	5	11	31	30	25	29	16	38	40	38	10	41	34	27
SUM OF FRAME GAUGES OVER 100μS (FR SUM)	3040	2465	11580	5730	7422	11500	3110	11420	17000	10165	8214	21339	12575	10883
FRAME AVERAGE (B/A) (FR AVE)	608	224	373.5	191	296	396	194	293	425	267.5	821.4	520	369	403
MAXIMUM FRAME STRAIN (FR MAX)	2000	300	1300	860	790	1140	380	670	1665	950	1762	1400	1240	1014
NO. OF PLATE GAUGES OVER 100μS (PL > 100μS)	5	6	19	17	14	15	6	20	19	20	11	26	15	15
MAXIMUM PLATE STRAIN (PL MAX)	270	300	800	620	800	915	350	850	1200	950	1856	1750	1400	1804
MAXIMUM SHIP SPEED (KNOTS)	4.0	16.32	12.72	6.3	3.40	6.09	6.91	29.77	16.73	6.21	7.62	11.69	4	2.90
MINIMUM SHIP SPEED (KNOTS)	1.5	1.38	0.70	0	0.39	0	0	0.09	0.88	1.44	4.22	0	0.03	0
AVERAGE SHIP SPEED (KNOTS)	1.0	6.5	6.82	3	1.52	2	2.2	8	6.6	4.6	5.88	1.28	2.2	0.79
AVERAGE THRUST (TONNES)	1.83	81.96	69.40	32	70.31	55	52	38	44	41.69	35.8	77	82	83.9
DURATION OF STATISTICAL OBSERVATION (MINS)	23	3	17	53	26	110	70	77	48	7	7	101	24	46

TABLE 4.2

CASE DESCRIPTIONS

OBSERVATION	TAPE I.D.	DESCRIPTION
BACKING & RAMMING		
BR#1	19-E	In 3/10 MY, 8/10 1st year
BR#2	22-A	1-4 knots (3 knots average)
BR#3	26-A	1-3 knots, 8/10 1st yr, 2/10 MY
BR#4	26-B*	(10 min) plus 5 knots continuous in 1st year.
BR#5	36-A	In LOUIS track, 1st year & 2/10 MY
BR#6	36-B	Heavy going in pack ice
BR#7	38-B	1st year and MY pack ice
CONTINUOUS TRANSIT		
CT#1	16-C	6/10 1st yr, 3/10 MY cont. transit
CT#2	20-A	8-10 knots 1st yr/ 1-4 knts Loose Pack (1/10 MY)
CT#3	20-B	2-5 knots 9/10 1st yr with leads/ Rams in MY rub.
CT#4	26-B*	Backing & ramming (10 min)/5 knots continuous in 1st year
CT#5	27-B	1st yr, 1/10 MY, 8/10 coverage continuous transit, 8 knots
CT#6	28-A	1st & 2nd yr ridged ice 3- 10 knots continuous transit
CT#7	28-B	7 knots 8/10 coverage 1st & 2nd yr loose pack
CT#8	32-A	4 knots continuous transit.

*Used in both backing and ramming and continuous transit cases.

CHART SUMM

	#FR > 100μS # FRAME GAUGES > 100 μS	FR SUM [μS] SUM OF FRAME GAUGES > 100 μS	FR AVE [μS] AVE. FRAME STRAIN	FR MAX [μ MAX. FRAM STRAIN
#FR > 100 μS				
FR SUM [μS]				
FR AVE [μS]				
FR MAX [μS]				
#PL > 100 μS				
PL MAX [μS]				
VEL AVE [kt]				

KEY:
(*): CORRELATION
( ): NO CORRELATION
(?): SOME BAD POINTS DESTROY CORRELATION
(BLANK): ANALYSIS NOT PERFORMED
BR( ): BACKING & RAMMING CASE
CT( ): CONTINUOUS TRANSIT CASE

TABLE 4.3

RY OF STATISTICAL ANALYSIS

]	# PL > 100 μS # PLATE GAUGES 100 μS	PL MAX [μS] MAX. PLATE STRAIN	VEL AVE[kt] AVE. SHIP SPEED	T AVE [MT] AVE. THRUST [TONNES]	VEL MAX [kt] MAX. SHIP SPEED
	BR(*)/CT(*)		BR(ϕ)/CT(*)		
	BR(*)/CT(*)		BR(ϕ)/CT(*)		
	BR(*)/CT(ϕ)	CT(*)	BR(ϕ)/CT(?)		BR(ϕ)
	/CT(ϕ)		BR(ϕ)/CT(?)		BR(ϕ)
		BR(*)/CT(*)	BR(ϕ)/CT(*)		BR(ϕ)
			BR(ϕ)		BR(ϕ)
				BR(ϕ)/CT	

FIGURE 4.5

M.V. ARCTIC: BACKING AND RAMMING CASES

TYPICAL PLOT OF PARAMETERS

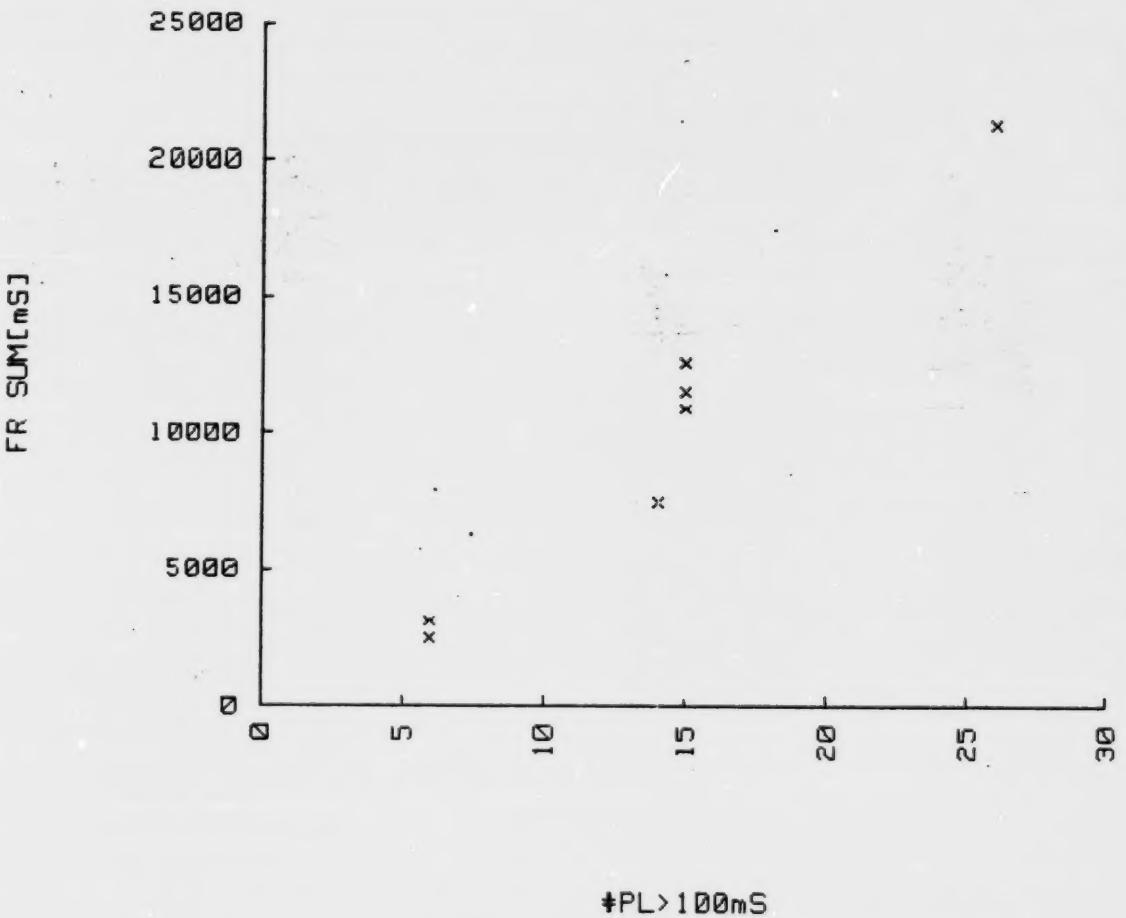
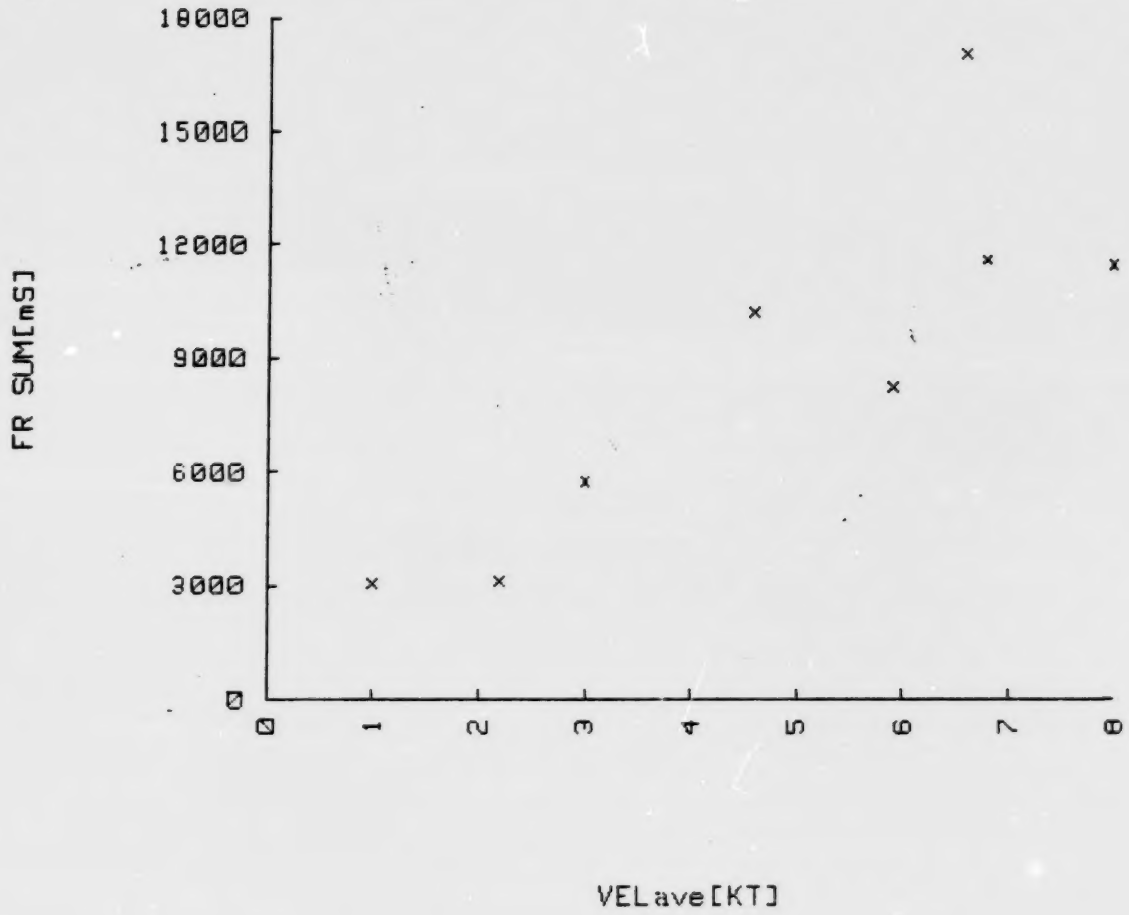


FIGURE 4.6

M.V.Arctic: CONTINUOUS TRANSIT CASES



(c) Recorded average thrust showed weak correlation with ship average velocity during continuous transit. This indicates 'unsteady-state' conditions during the sampling return period and further analysis of the log and selection of the return period is required.

(d) The extent of activity as measured by the number of plate gauges over the threshold strain value correlated with that as measured by the number of frame gauges over the threshold.

(e) In the 14 cases selected, two returned maximum frame stresses beyond the yield of the material, and 11 over ½ yield stress. The plate gauges showed 4 cases where the maximum stress was beyond yield, and again 11 were over ½ yield stress. Cases where yield was exceeded must be identified in subsequent analysis, as results from rebalanced gauges may not be meaningful.

(f) When operating in the track of the icebreaker the gauges indicated a considerable amount of high load activity. This was as a result of the track closing rapidly behind the breaker under dynamic ice conditions.

(g) The recording of ship speed by the doppler log is unreliable as exemplified by the readings in Case BR#1. Close examination of the output shows normal ship speeds around 3 knots, yet readings of over 16 knots were recorded for one sampling period, greatly affecting the average reading also.

(h) Trend analysis such as this may prove to be the most useful technique for obtaining useful data from the MV ARCTIC statistical data.

In general the analysis shows that this gross statistical analysis method produces expected results from continuous transit ice data and little in the way of statistical trends between parameters from backing and ramming.

This is perhaps to be expected since a statistical analysis of a 30 minute ramming period combines rams of different speeds, loads and areas into one data set. To produce reasonable data from rams one must analyze these with time-series methods in order to relate a ship velocity with the correct strain level.

The rest of the plots can be found in Appendix E.

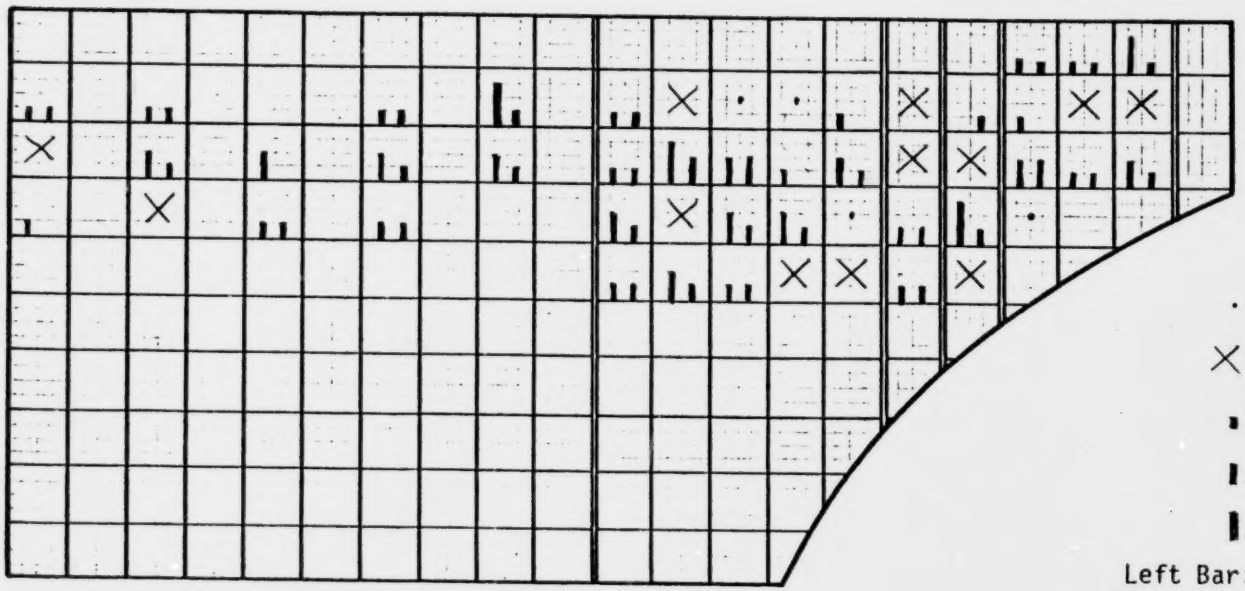
A comparison of stresses for two different types of ship/ice transit was made using the data from tapes 27 and 42. Qualitative assessment of the relative magnitude of strains between backing and ramming in multi-year ice and level 1st year ice transit is shown schematically in Figures 4.7 and 4.8 for frame and plate strains respectively from which it can be seen that the strains in the multi-year ice condition are much higher.

FIGURE 4.7

COMPARISON OF BACKING AND RAMMING
AND CONTINUOUS TRANSIT: FRAME STRAINS

BACKING AND RAMMING
November 12, 2318-0105 GMT 7/10 1st yr, 1/10 2nd yr, 2/10 MY in pack ice

CONTINUOUS TRANSIT - November 8/81
8 knots
8/10 1st yr, 2/10 MY



.: Working Gauge

×: Bad Gauge

▪: <500μS, >100μS

▮: >500μS, <1000μS

▮: >1000μS

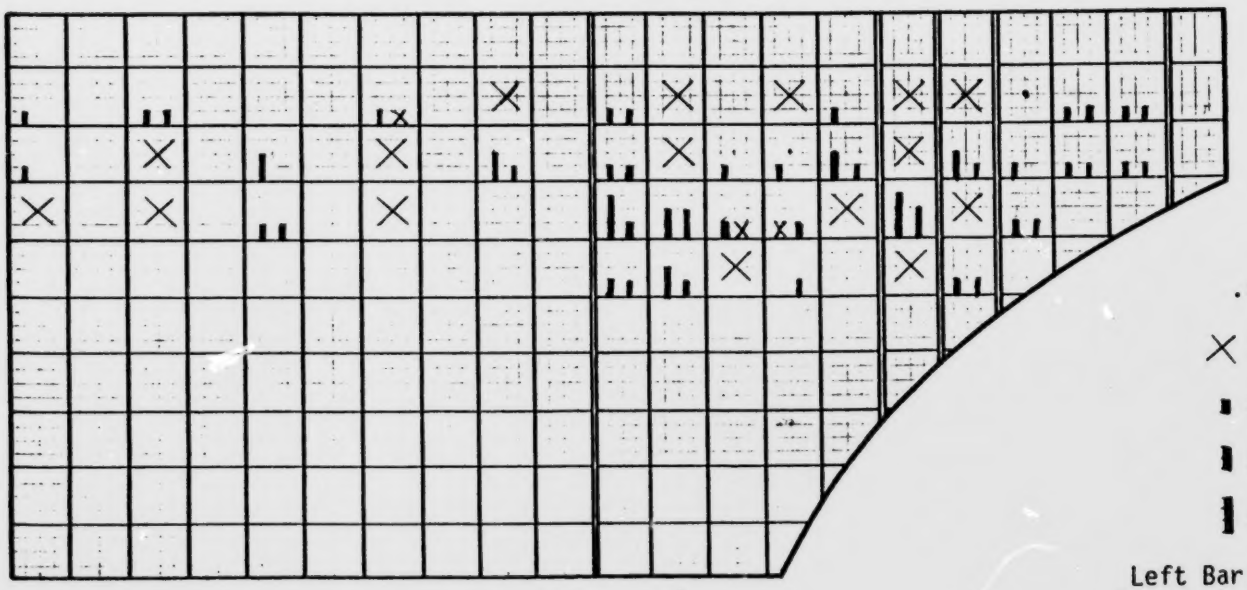
Left Bar: Backing and Ramming
Right Bar: Continuous Transit

FIGURE 4.8

COMPARISON OF BACKING AND RAMMING
AND CONTINUOUS TRANSIT: PLATE STRAINS

BACKING AND RAMMING
November 12, 2318-0105 GMT 7/10 1st yr, 1.5/10 2nd yr, 1.5/10 MY in pack ice
(see Gen. Log)

CONTINUOUS TRANSIT - November 8/81
8 knots
8/10 1st yr, 2/10 MY



.: Working Gauge

×: Bad Gauge

▮: <500μS, >100μS

▮: >500μS, <1000μS

▮: >1000μS

Left Bar: Backing and Ramming
Right Bar: Continuous Transit

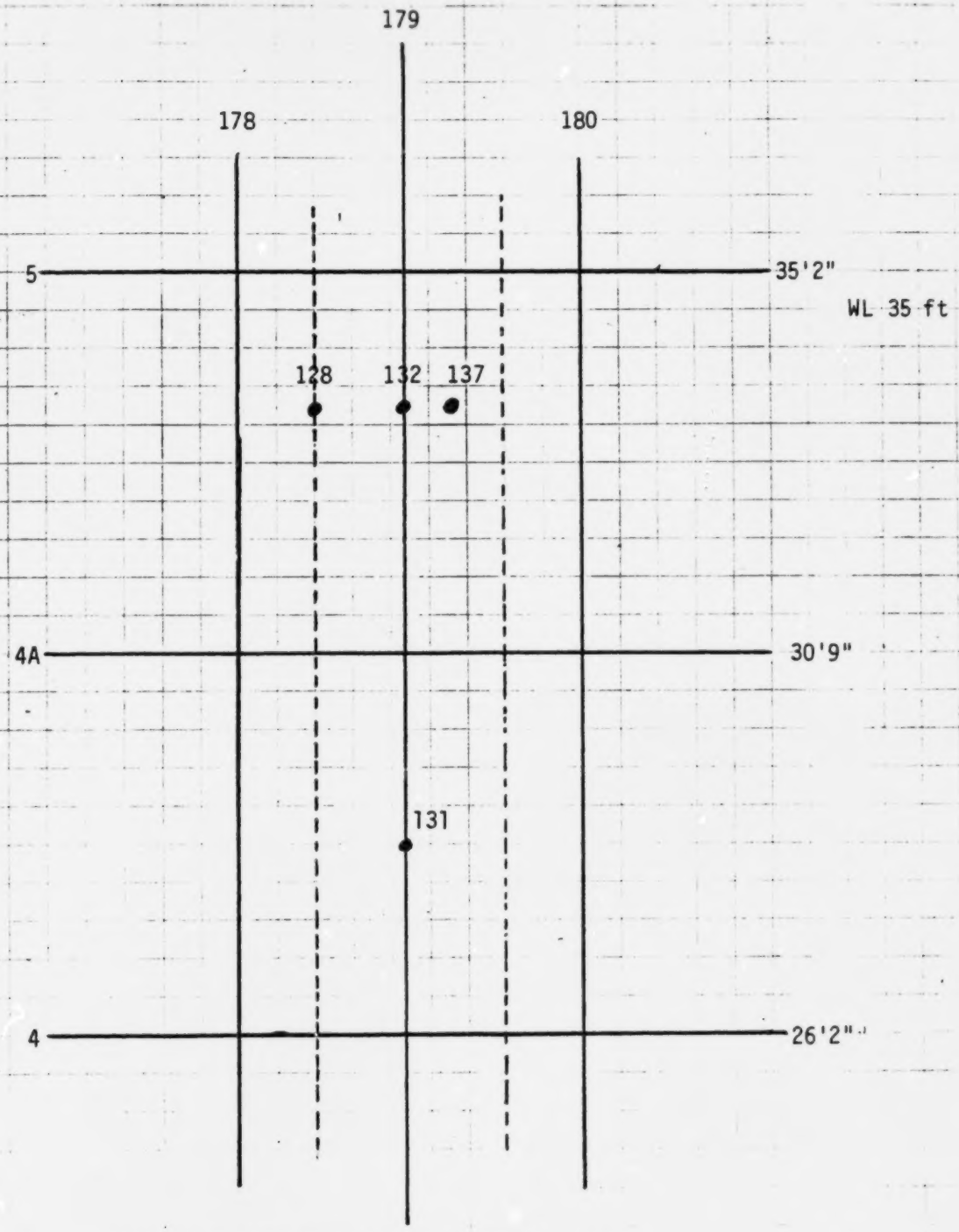
4.4 Discrete Impact Analysis

During the late season some heavy ice conditions were encountered and a number of discrete impact cases were identified during data reduction for further analysis. Three of these impacts resulted in apparent yielding of the structure as evidenced by significant zero shifts of specific strain gauges. Due to the limited amount of data reduction time available on the ship and the large number of tapes which required statistical analysis, an indepth study of these and other impacts was not possible.

Two of the three cases discussed in the following occurred during the period when the test team were onboard for dedicated testing However they did not occur while actually executing a controlled ram head on, but rather while maneuvering to a position to ram multi-year ice. Indeed these two cases were not identified by the dedicated test team as being 'significant' in terms of hull response. Nevertheless it should be noted that neither case of the first two cases represents 'normal operations' in that multi year ice was not being deliberately avoided. The third case however is representative of late season normal commerical operations.

The first case of permanent structural deformation occurred during the first day of the dedicated ice trials on November 4, 1981. Four gauges, three frame and one plate, failed during an approximate 5 knot ram into multi-year ice. The resulting amplifier saturation caused a transient in the bus which caused the computer to stop writing data to the tape drive. This is consistant with problems discussed in Appendix B. The three frame gauges, channels 128, 131, 132 are illustrated in Figure 4.9. An adjacent plate gauge, channel 137, also failed. Note that the upper gauges failed in the tensile direction and the lower failed in the compressive direction. This implies that the ice contact area was concentrated at about the 32 ft level. Due to the computer crash no data exists describing the rise times of these or other gauges. Investigation from the ice at a later date confirmed plate damage in this area. All four gauges were rebalanced with little difficulty but further results from these channels must be interpreted carefully since the gauges may be damaged or strained into a non-linear region.

FIGURE 4.9
GAUGE FAILURES



128, 132, 137 failed in tensile direction
131 failed in compressive direction

The second obvious case of structural change was detected from data collected by the analogue tape recorder. Once again the failure coincided with a significant ram as noted in the tape log (see Appendix A Nov.6 1850 hrs). Since the zero shift occurred at the beginning of the computer file it was not immediately obvious that the shift occurred from an impact rather than the assumed thermal drift. Figure 4.10 is a reproduction of the analogue playback illustrating the magnitudes and rise times of the strains. Figure 4.11 illustrates the track of the load across the hull. Channel 89, 91, and 156 are seen to have zero shifts after the impact.

Channel 91 recorded a maximum stress below yield (40,000 psi). The complex pattern of tensile and compressive stresses requires further investigation. It would appear that the main frames buckled and tripped in classical fashion and the gauges recorded compressive and tensile strains. This would suggest that the location of the gauges on the frames was less than ideal. However, the fact that permanent strain was registered at strain levels below yield suggests that the set was due to failure in remoter parts of the structure. Finally, there is always the possibility that the gauges themselves detached from the structure. To fully understand what load level caused the observed complex structural response requires a sophisticated finite element analysis using a program which can handle both non-linear geometry and non-linear material properties.

Note that Figure 4.11 indicates the damaged area as reported in the hull survey report [7]. A brief analysis of this damaged area using a classical approach based on the formation of plastic hinges indicated the damaging load to be of the order of 33 MN or 7.76 MPa pressure (1129 psi).

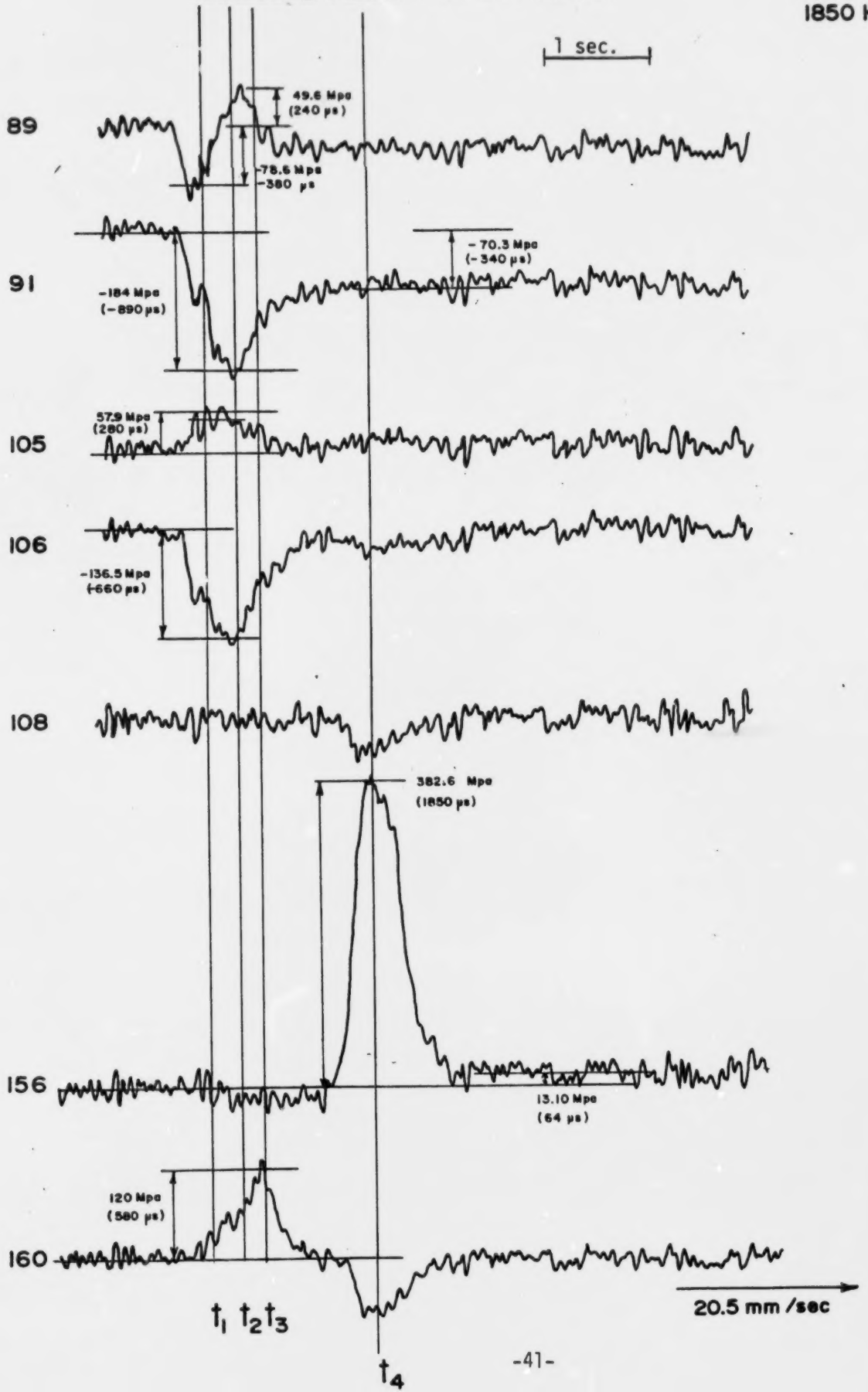
Table 4.4 compares the maximum strains from the analogue recorder with those from the computer. Note that this comparison is only valid if there were no larger strains subsequent to the yield strains since the computer analysis covers 20 minutes after the impact. The two values do not compare favourably and a detailed discussion of analogue and digital recording errors is presented in Appendix D. All gauges were rebalanced with no difficulty after the zero shift was noted.

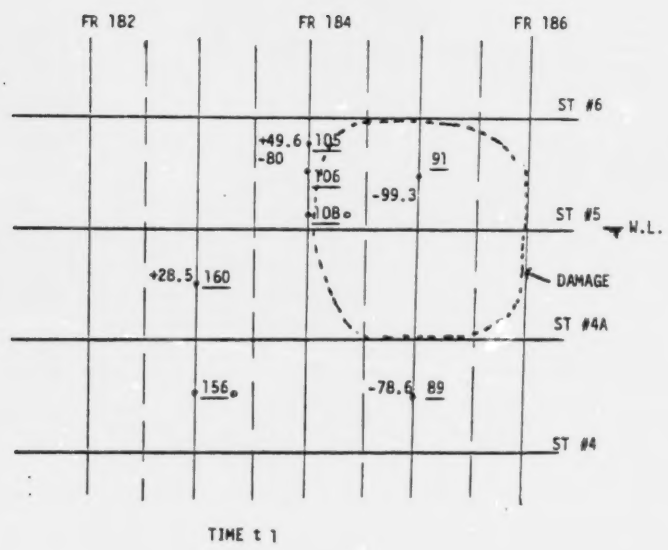
The next case to be presented is a direct comparison of computer statistics versus analogue statistics in identical time frames during an impact with multi-year ice on November 8, 1981 at an average speed of about 5 knots. Figure 4.12 is the analogue record of the time frame, Table 4.5 is a comparison of maximum strains as seen by the computer versus the analogue record and Figures 4.13 and 4.14 illustrate the location of active gauges for this one impact. Once again there is a discrepancy between computer and analogue peaks with the analogue values being high again.

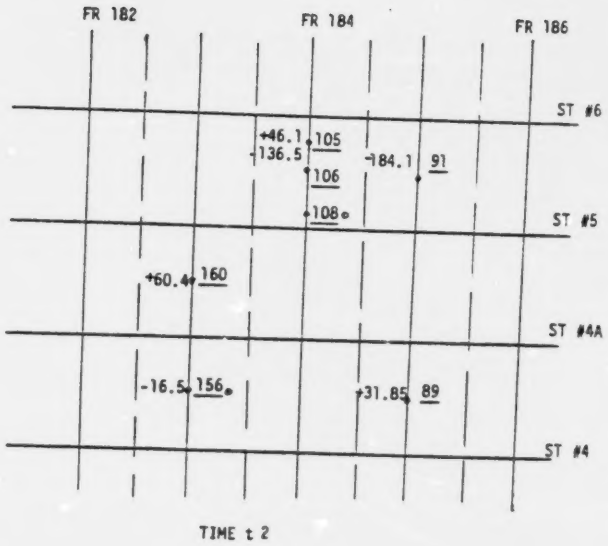
FIG. 4. 10

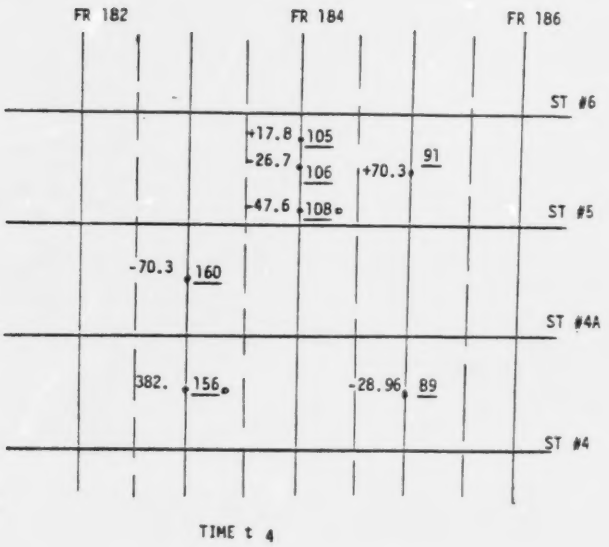
ANALOGUE PLAYOUT OF 2ND IMPACT

NOV. 6
1850 HRS.









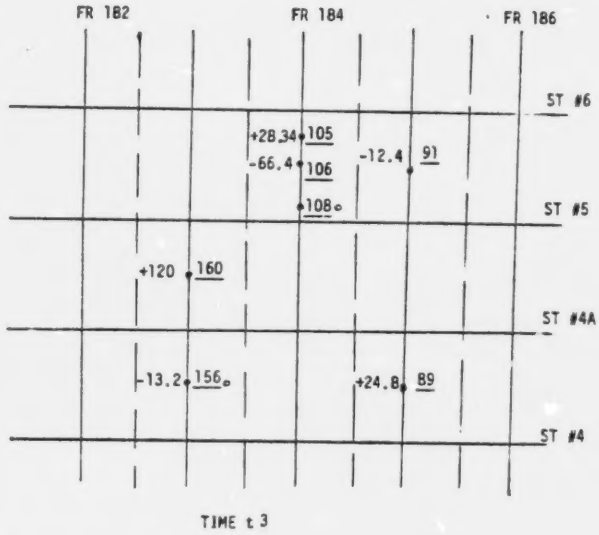


FIGURE 4.11 STRAIN MEASUREMENTS DURING ONE IMPACT
ALL VALUES IN MPa

FIGURE 4.12

November 8/81: ANALOG RECORDER

AVERAGE SPEED = 5 kts

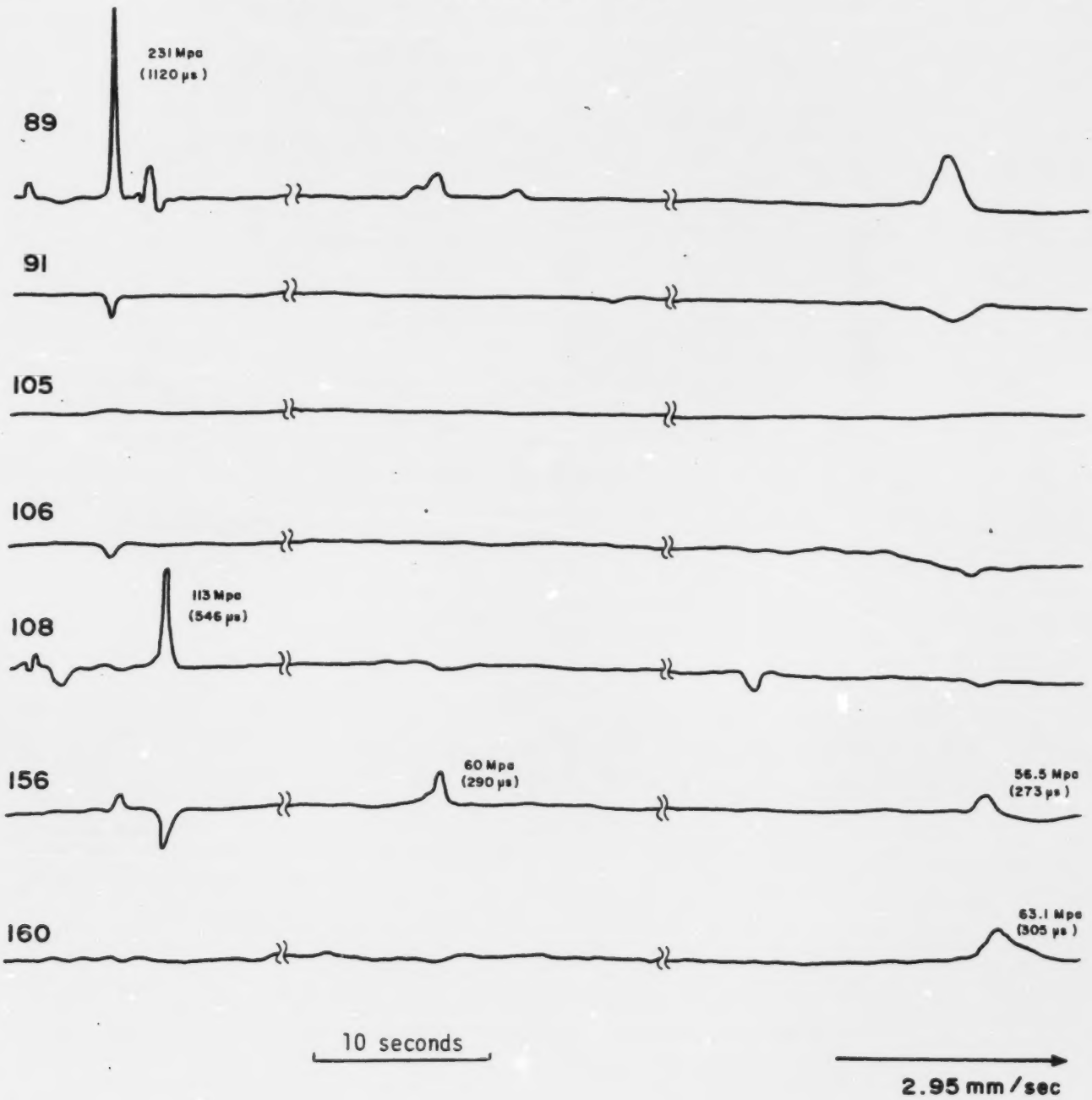


TABLE 4.4

YIELD ON NOVEMBER 6, 1981 - 1850 HOURS

CHANNEL COMP.	CHANNEL REC.	ZERO SHIFT REC.	MAXIMUM* COMP.	MAXIMUM* REC.	AVERAGE (COMP)
89	1	-140μS	325μS	240μS	-219
91	2	-340μS	- 32μS		-321
105	3	0	154μS	280μS	- 17
106	4	0	- 31μS	-	- 71
108	5	0	- 23μS	-	- 4
156	6	+ 64μS	1623μS	1850μS	29
124	7	0	426μS	-	195
160	8	0	400μS	580μS	- 95

*Not average adjusted

TABLE 4.5

COMP / REC. CHANNELS		MAXIMUM COMP.	MAXIMUM / REC.
89	1	950μS	1120μS
91	2	-	0
105	3	-	0
106	4	-	0
108	5	-	546μS
156	6	170μS	290μS
160	8	180μS	305μS

FIGURE 4.13 STRAIN GAUGES MV ARCTIC (FRAME)

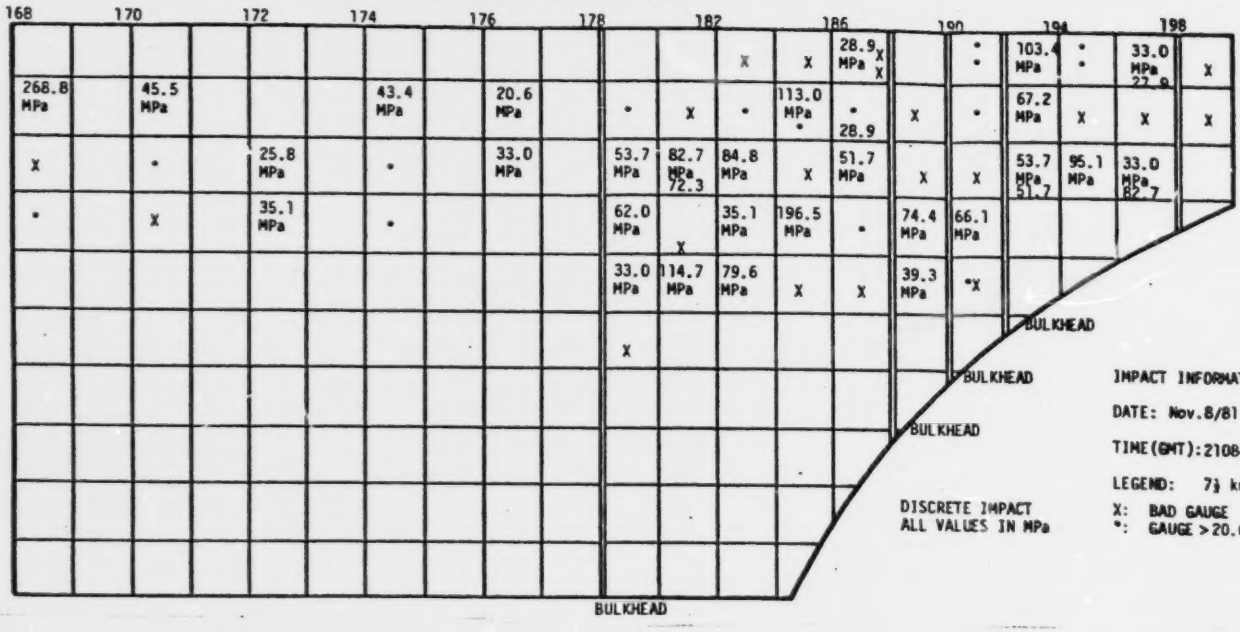
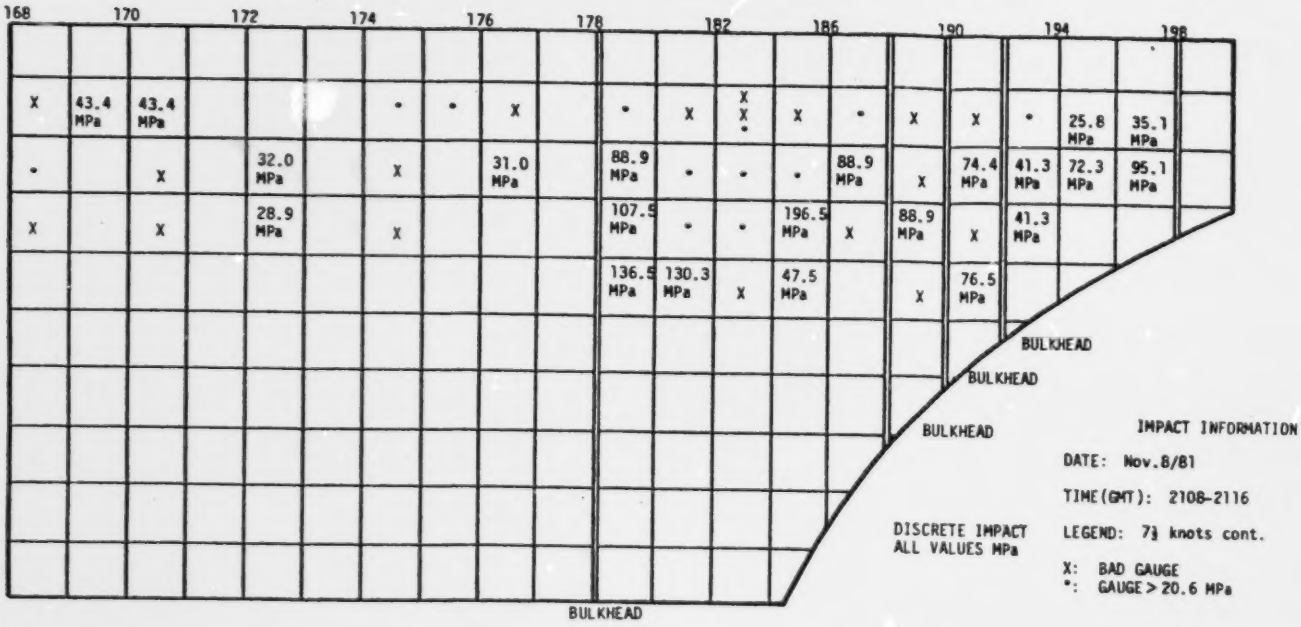


FIGURE 4.14 STRAIN GAUGES MV ARCTIC (PLATE)



On November 12, 1981 on the last trip out of Nanisivik (with the analogue recorder returned to Ottawa) another gauge failure occurred in multi-year at 6 knots. Channels 89 and 94 (frame and plate respectively) failed resulting in amplifier saturations, followed by high strain levels on 21 other gauges all of which returned to zero. Figure 4.15 is a peak value time series of 10 of these gauges, and Figures 4.16 4.17 illustrate the maximum strains recorded at all locations.

Once again plate and frame gauge failures and strains coincide geographically. The time series plot of Figure 4.15 shows the transfer of load from fore to aft, top to bottom. The gauge location shows that most of the load was absorbed 9 feet below the water line (stringer #4).

From the analogue recorder a number of strain sequences have been analyzed for rise times as seen in Figure 4.18. Table 4.6 summarizes these rise times, peaks and pulse durations. Referring to Appendix C one can identify which frames are major frames and which are intermediates as noted in Table 4.6.

4.5 Ice Trials

On November 1, 1981 eight people joined the ship to perform dedicated tests with the ship ramming multi-year ice. The objective was to measure overall hull response during the rams. This test team installed instrumentation to measure deck plate stresses and two video cameras (port and starboard) to monitor ice breaking patterns forward of frame 184. These ramming tests were performed on November 6, 7 and 8. Fifteen ramming cases were identified by the test team as being significant loads on the starboard bow gauges. The operator recorded data and played it back primarily in order to supply ship speed data. The strain gauge data (Table 4.7) reveals very little activity for these 15 cases. The test team actually identified more than the 15 ramming cases presented in Table 4.7, however due to computer thermal problems discussed earlier the system was not operational for these other cases.

The results indicate that the problems of loading on the shoulder of the vessel, local load, and that of overall hull response during head-on rams are quite independent as the level of gauge response was not high.

NOV 12/81
@ 0047:04

FIGURE 4.15

PEAK VALUE TIME SERIES

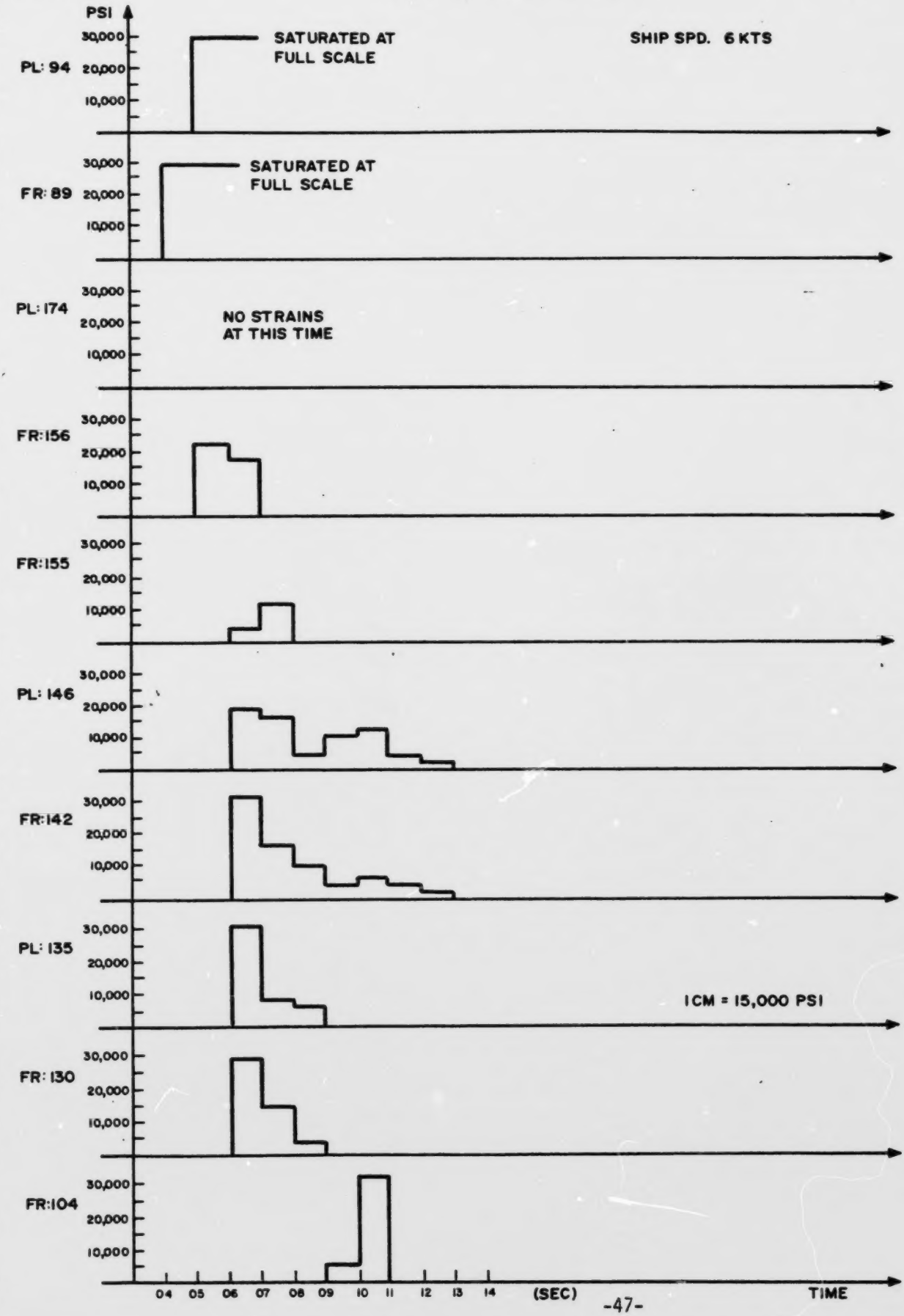


FIGURE 4.16 STRAIN GAUGES MV ARCTIC (PLATE)

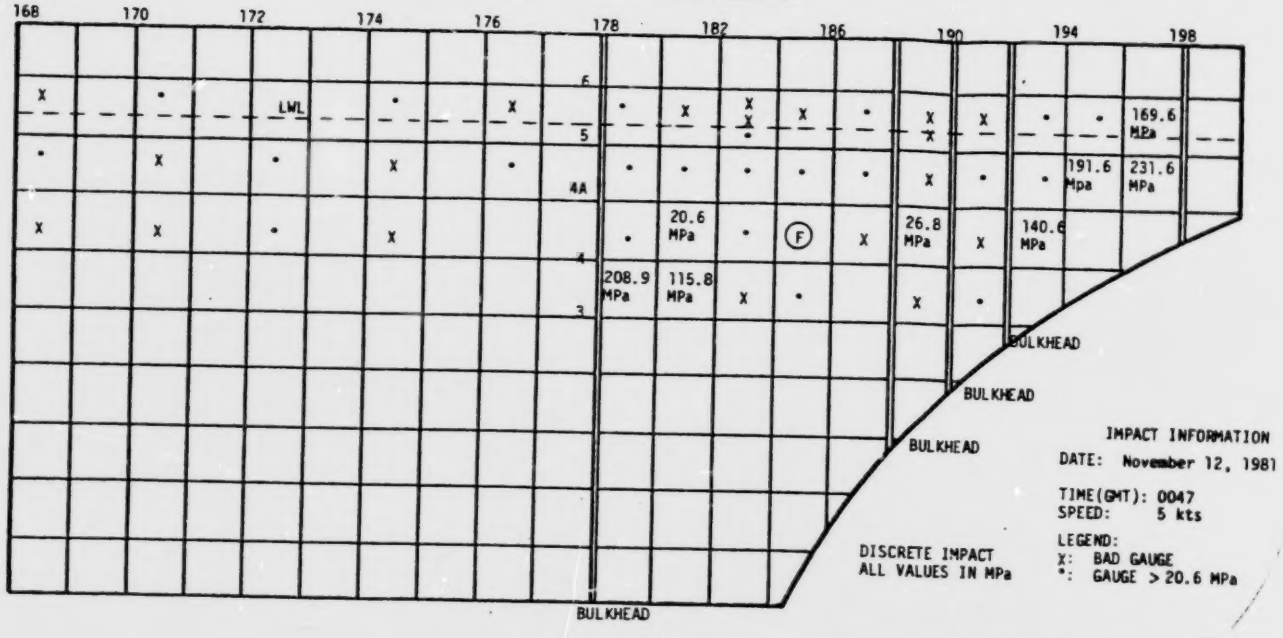


FIGURE 4.17 STRAIN GAUGES MV ARCTIC (FRAMES)

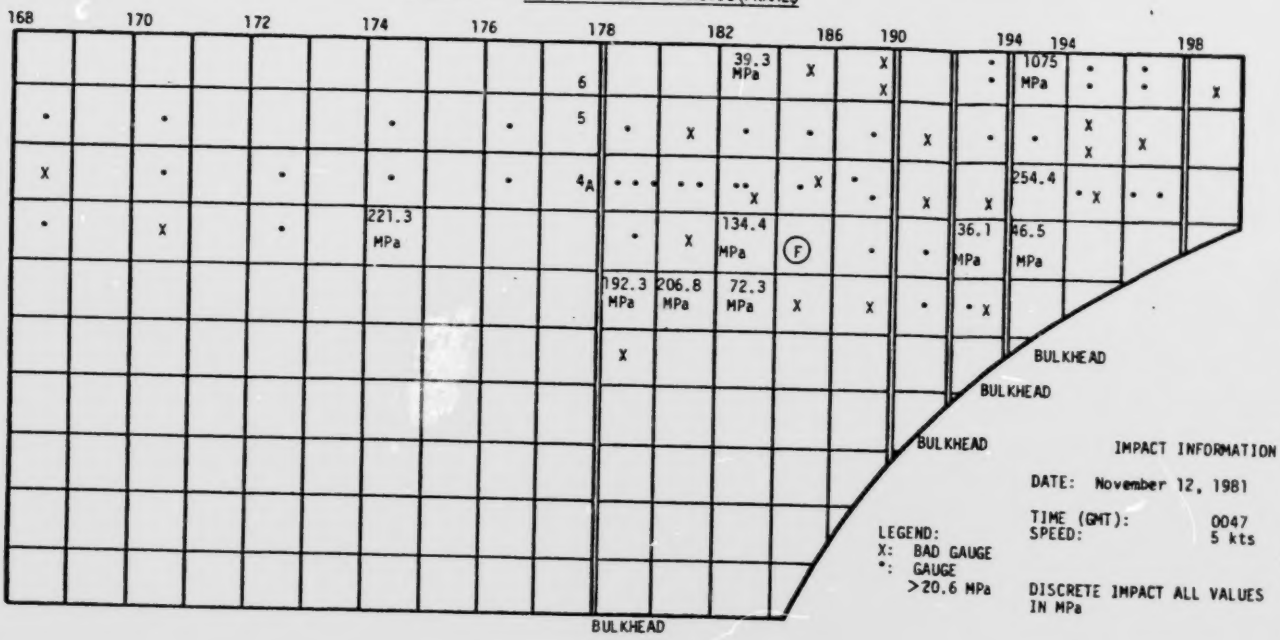


FIGURE 4.18
TYPICAL STRAINS
November 8/81 ANALOG RECORDER

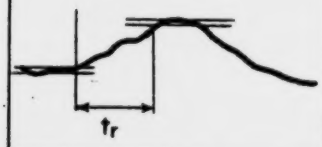
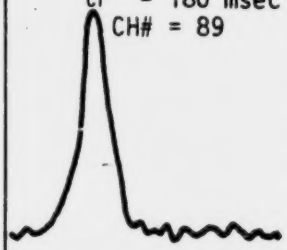
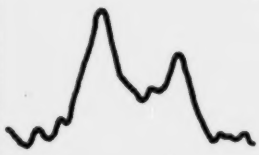
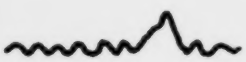
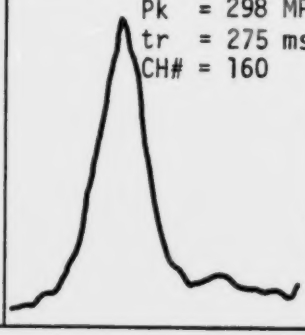
1948 GMT	2052 GMT	2039 GMT	2110 GMT
Pk = 63.09 MPa tr = 690 msec CH# = 156 	Pk = 64.12 MPa tr = 470 msec CH# = 89 	Pk = 42.40 MPa tr = 110 msec Ch# = 89 	Pk = 232 MPa tr = 180 msec CH# = 89 
Pk = 51.70 MPa tr = 140 msec CH# = 89 	Pk = 59.98 MPa tr = 260 msec CH# = 156 	Pk = 122 MPa tr = 200 msec CH# = 108 	Pk = 113 MPa tr = 315 msec CH# = 108
Pk = 60.4 MPa tr = 390 msec CH# = 89 	Pk = 39.71 MPa tr = 160 msec CH# = 156 	Pk = -39.3 MPa tr = 140 msec CH# = 156 	2119 GMT Pk = -80.57 tr = 200 msec CH# = 106
PK = 56.47 MPa tr = 510 msec CH# = 108 	Pk = 39.71 MPa tr = CH# = 160 	Pk = stress maximum tr = rise time Note: Rise time is defined as the time required for the strain to rise from 10% to 90% of its final peak value.	Pk = 298 MPa tr = 275 msec CH# = 160 

TABLE 4.6

CHANNEL/FRAME	PEAK STRESS/ STRAIN	RISE TIME [msec.]	STRAIN DURATION [msec.]	NOV.8/81
89 Main	51.70 MPa (250μS)	140	335	1948 hrs
89 Main	60.40 MPa (292μS)	390	1560	"
108 Web	56.47 MPa (273μS)	510	768	"
156 Main	63.09 MPa (305μS)	690	1300	"
89 Main	64.12 MPa (310μS)	470	810	2052 hrs
156 Main	59.98 MPa (290μS)	260	551	"
156 Main	39.71 MPa (192μS)	160	217	"
89 Main	42.40 MPa (205μS)	110	433	2039 hrs
108 Web	122.04 MPa (590μS)	200	866	"
156 Main	-39.30 MPa (-190μS)	140	768	"
106 Web	-80.67 MPa (-390μS)	200	1122	2119 hrs
160 Main	297.85 MPa (1440μS)	275	709	"
89 Main	231.66 MPa (1120μS)	180	394	2110 hrs
108 Web	113.07 MPa (546μS)	315	1043	"

TABLE 4.7
Selected Cases for Ramming Trials

CASE	DATE	TIME OF IMPACT	GAUGES > 50μS (BY CH. #)	MAXIMUM STRAIN (μS)	IMPACT VELOCITY (KNOTS)
1	Nov. 6/81	1900:46-1901:08	50	81	4.5
			128	157	
			132	227	
			135	91	
			137	210	
			142	51	
			146	103	
			166	130	
			169	70	
2	Nov. 6/81	2032:36-2032:59	ϕ > 50μS		3
3	Nov. 6/81	2044:06-2044:43	52	76	2.5
			54	572	
			58	832	
			63	87	
4	Nov. 7/81	0032:46-0033:06	ϕ > 50μS*		7**
5	Nov. 7/81	1606:35-1606:45	43	57	4
			102	151	
6	Nov. 7/81	1616:20-1616:43	ϕ > 50μS		3
7	Nov. 7/81	1629:55-1630:26	93	75	3
			135	68	
			146	65	
8	Nov. 7/81	1639:25-1639:45	ϕ > 50μS		3
9	Nov. 7/81	1642:36-1643	ϕ > 50μS		
10	Nov. 7/81	1706:31-1706:51			3
11	Nov. 8/81	1649:06-1649:51			2
12	Nov. 8/81	1651:26-1651:41	ϕ > 50μS		2
13	Nov. 8/81	1653:31-1653:55			2.5
14	Nov. 8/81	1655:51-1656:14			
15	Nov. 8/81	1658:16-1658:37	65	99	2.2
			70	50	
			73	265	

**No speed change: incorrect time?

4.6 Guidance for Future Analysis

Based on our experience the following is offered as guidance for future analysis of the statistical type of data.

It is strongly recommended that individuals performing further analysis on these tapes read the maintenance log to fully appreciate the implications of system problems. Malfunctions such as the auto zero circuits cycling sporadically make the usefulness of some of the acquired data questionable. Upon entering ice on November 1, 1981 the operator felt that the system was acquiring data as designed. From this point on the operator concentrated his efforts in acquiring ice data and operating and checking the system as recommended in the operating manual.

Individuals performing indepth analysis of the data on tape have the following information available to them.

1) Printouts from LOG function of the data acquisition systems. These are dumps of all the system channels at a specific point in time performed typically every 10 minutes while acquiring data.

2) Video tape from masthead camera. Note that time/date information is only present prior to September 1981.

3) The operators log of tapes describing the type of data collected in terms of ice conditions and ship motion (continuous transit, backing and ramming).

4) Photographs of ice conditions at various points in the voyages.

5) Statistical analysis of data including:
   a) a time series dump of up to 10 channels of propulsion data printed every 15-20 seconds during the statistical analysis of the data,
   b) statistical output summarizing the data in terms of maximum, minimum and average strain levels during the analysis,
   c) sampling pattern used to acquire data including the sampling rates,
   d) time/date information as initialized.

6) System status as assessed by the operators at various times during each season.

A program for further analysis of the data reported herein form:

1) Initally concentrate the analysis on tapes that have already been reduced statistically by the operators. This is because these have already been 'screened'* for value and quality.

2) Examine tape log where computer anomalies, ice data, etc. are listed.
Select tapes by studying all logs, system status, video, photographs and statistical outputs of the preliminary data reduction.

3) Study the time series data from LOG outputs (real time) and statistical MONITOR outputs to home in on specific periods of time, for example:
- 1 hr of continuous transit at 5 kts ± 1 kt in 1st yr ice, and to eliminate data for which 'bad' values (e.g. doppler) are present.

4) Run the statistical analysis program over this selected period of time.

5) Run a "time series plot" program on the specific period having selected only those channels of interest as assessed from the statistical analysis. This program should only plot peak strain gauge channels once per second and the results should be similar to Figure 4.15. Such a time series plot of strain data would reveal any false signals such as zero drift.

6) Run any specific analysis programs (such as load analysis) on this select time period having been assured of the validity of the data from the time series plots in (5).

The basic philosophy is to be selective on the periods analyzed looking only at those periods which have good ice documentation as assessed from the video tapes and operators' logs.

*FOOTNOTE:

The initial screening by the operator is an important element as his initial judgement of what constitutes quality data includes elements and considerations which are not easily documented. Quality screening reflects his assessment of the system status including the reliability of sensors, the computer operation and whether or not a video record is available to provide environmental data etc. 'Value screening' is his assessment of the usefulness to designers, etc. of the type of ship/ice interaction, and, on this occasion, his efforts reduce a wide variety of ship/ice interaction.

This initial screening and assessment of data quality by the operator is essential to successful data analysis and it is for this reason that ARCTEC always employ the operator of the system in the data analysis stage of its field projects.

5. DISCUSSION OF FINDINGS

A. System Maintenance and Operation

1. The level of maintenance effort on the system was in our opinion high, requiring more or less continuous maintenance for the several weeks prior to operations in ice. Indeed during operations in ice a full-time onboard maintenance technician would have been of benefit in freeing the operator for more data recording and reduction.

2. It is not possible to judge if the maintenance effort is becoming greater due to 'ageing' of the system, since this contractor has no previous experience with this system. It does seem however that some system crashes due to burnt out circuit boards are due at least in part to the necessity to remove and replace these during system troubleshooting.

3. Another maintenance problem due to overheating has been reported in previous seasons and recommendations made for installing air conditioning. We would support that fully if further years of operation are contemplated.

4. Gauge drift continued to be a major problem and required correction on a daily or more frequent basis. This degree of gauge drift is neither acceptable nor necessary and is a reflection of the gauge quality and the installation. In addition the process of re-balancing the gauges is somewhat tedious and difficult due to there being no provision for doing so from the computer room. Typical gauge drifts were of the order of 100 $\mu\varepsilon$.

5. The absence of an analogue print-out or signal at the computer to assist in diagnosing problems is a considerable inconvenience. A six or eight channel chart recorder with a de-multiplexing interface would permit the operator to inspect selected channels periodically to assist in trouble-shooting.

6. The video camera and housing were in poor shape and required replacement. This was partly due to ageing, but also due to choice of components and installation. The environmental housing was not weatherproof as it had vent holes to permit air circulation to the processing equipment in the housing. Consequently corrosion existed inside the housing.

7. These system maintenance problems are well documented in Appendix B and in Appendix F an operator's troubleshooting guide has been produced to assist in maintaining the system operational. These should be read in conjunction with this report. The troubleshooting and maintenance guide presents guidance for future system maintenance.

B. Data Reduction and Analysis

8. With gauge zero shifts and the zero offset discussed in Appendix D the values of microstrain printed in the statistical output must be considered to be accurate to about + 100 με (50 to 150 με) only. For this reason, statistical data at low levels of microstrain is of doubtful value. For example histograms and peaks in the range of 0 - 300 με with 50 με divisions may demonstrate only the amount of noise in the system, and may completely misrepresent the mode of the distribution. Our onboard data reduction therefore concentrated on higher level impacts.

9. The selection of tapes made for onboard data reduction was based on those felt to include significant ship/ice events, and which were not affected by computer shut-down. The objective was to establish trends in parameters which it was felt would be measures of ship performance, in order to present a data analysis technique not previously reported. Of course all outputs are available for generation of histograms. The type of assumptions which are made in Section 4.3 with respect to the relationship between available measured parameters (e.g. Sum of Frame Strains) and the desired parameters e.g. Load - are useful. This technique should be applied to the other data from earlier seasons to see if the trends are confirmed.

10. The levels of strain measured during this season were greater than those measured and reported previously. Examples are, tape 39A, recorded while following in the wake of CCGS LOUIS S.ST. LAURENT where strain gauge readings of 530, 613, 740 με were measured during a short period of transitting the LOUIS wake. In backing and ramming later (November 12th) over a period of about 1 3/4 hours, in darkness, 25 gauges showed maximum peaks over 500 με, some as high as 1100 με. Only 3 of the latter must be corrected for apparent zero shifts. These levels compare with values reported in earlier seasons of up to 350 με in level ice and with tape 27 up to 8 knots in up to 8" ice where only 3 gauges exceeded 500 με and most were registering maxima around 200 με.

11. By following the procedure outlined in 4.6, careful selection of tapes and recording periods can be made, and the amount of data may be reduced to a size that will practically allow the recognition of anomalies, elimination or correction of faulty readings, etc.

12. The purpose of the statistical data collection technique in MV ARCTIC is to assist designers and regulators. In a manner analogous to that used to modify the traditional approach to longitudinal strength of a ship in waves, long-term statistical data may be used to extrapolate to the "25-year load" or the "load with only.5% chance of lifetime exceedance". For wave statistics many hundreds of ship-years and ship miles of data were collected before a reliable statistical design approach could be contemplated. In a similar fashion, the objective is to collect statistically meaningful examples of the ship operating in ice and use established statistical techniques for predicting extreme values from the measured sample. By comparison with the wave data, due to the limited amount of shipping in ice covered waters, the data base is very small. Further, based on the preliminary review herein, it is our opinion that the technical problems experienced with the recording system may have greatly reduced the quantity of useful data available in the data base, and made the task of extracting a sample of sufficient quality for prediction of extremes most difficult.

13. With the currently available sampling rate, the ability of the system to characterize ship/ice interaction effects is severely limited. For example, to correctly characterize shaft torque fluctuations during ice milling, sampling rates of around 150-200 Hz are required. To usefully relate this to other ship system characteristics one would also want to record RPM fluctuations, ship speed and a number of other channels, rapidly absorbing the available sampling rate. Likewise, total load determination from strain gauge records may require more than 12 gauges sampling at over 100 Hz. Thus the data analyzer must be cautious in interpreting results.

14. Recommendations for system improvement previously made have not been carried out (improved gauge quality, air conditioned room) and consequently the system is being operated on a "make-do" basis. It seems that the decision must be made soon either to upgrade or de-commission the system.

15. Our experience on this contract, when compared with our considerable experience on many other data collection programs leads us to conclude that dividing responsibility among several contractors does not lead to efficient use of resources. Not only do areas of responsibility become cloudy so that maintenance of an operational system is jeopardized (eg. the date-time-generator) but understanding of the data quality by subsequent analysis is often most difficult, as witnessed by the many questions arising after completion of this contract.

6. CONCLUSIONS

A. Instrumentation System

1) The MV ARCTIC data acquisition and recording system is considered to require excessive maintenance, is unreliable and difficult to fault find. (See Appendices B and F).

2) Some of the maintenance problems may be attributable to aging, (integrated circuit boards), but some are aggravated by poor system/component choice and or installation (e.g. video housing, strain gauges).

3) Some of the failures experienced this year have been reported previously along with recommendations which were not carried out.

4) Statistical outputs must be examined carefully to remove or correct for zero drift (usually limited to 100 $\mu\varepsilon$), zero shift, spurious signals (e.g. doppler log).

5) When compared with balanced output from an analogue recorder the digital system exhibited a zero offset value which will affect absolute values used when operating in the peak mode only. In addition low levels of strain should not be reported in histogram as they are most likely due to system "noise".

6) The sampling pattern is crucial to the collection of useful data, yet an incorrect choice of sampling pattern can cause the computer to reject sensors if the available sampling capacity is exceeded. A sampling pattern such as that named 'A' herein should be selected and retained. It will require changing as sensors fail.

7) Should data collection continue with this system, the operator should concentrate on collecting strains from around 25 gauges in the shoulder area where impact frequency is high.

8) A number of gauges failed permanently or intermittently during the season. These should be replaced with relocated high quality gauges. This relocation could include positioning such as to avoid losing the gauge when localplate yield occurs.

B. Data Analysis

9) Extreme care must be taken prior to data analysis to check the validity of the data in a given record period, by referring to the maintenance and operator's log and by following a systematic sequence of screening such as has been set out on page 51.

10) Loads imposed on the hull due to head-on ramming do not affect the level of stress in the shell at the shoulders. Ice impacts causing high loads at the shoulders do not necessarily cause high stress levels in the main hull girder.

11) Load levels during operations following in the track of an icebreaker in dynamic ice conditions are high, strain readings of up to 750 $\mu\varepsilon$ being recorded on such occasions.

12) Strains experienced while moving in multi-year ice are of the order of 2-3 times those experienced in the wake of a breaker, and 3-5 times those experienced during level ice transit. Typcial examples are 1100 με while backing and ramming in MY ice, 700 με in the wake of a breaker and below 500 με in level ice.

13) Generally when navigating cautiously in a low percentage of multi year ice, the ship will not experience damage. However, when backing and ramming in multi-year ice at the end of the season, severe loads resulted in permanent damage to the ship. In view of the susceptibility of this vessel to damage by multi-year ice, if not navigated so as to avoid it, its use as a test bed for examining extreme ice loads is <u>not</u> recommended.

7. RECOMMENDATIONS

1) Continued use of the current MV ARCTIC instrumentation system to explore the phenomenon associated with ship/ice interaction is not recommended until the value of the current data is assessed.

2) In view of the ship operating cycle which results in a relatively small proportion of operating time being spent in ice, it is essential that the data acquisition system be both *reliable* and technically capable of recording the data with the required degree of accuracy and confidence. For this purpose we recommend that future systems consist of a microprocessor based digital recording system, a *reduced* number of quality sensors, provision for additional analogue recording during dedicated test periods, and an on-board chart recorder or oscilloscope for real-time analysis of key data. In addition a suitable environmentally controlled location should be provided for the instrumentation.

3) If on-going long term statistical data collection is required, a system incorporating fewer, more reliable sensors and data transmission hardware, *unmanned* solid state peak detectors and memories and facilitating periodic system check-out should be designed. Higher initial cost would be offset by reduced operation and maintenance costs.

4) The configuration of MV ARCTIC is such that it is capable of providing most useful data on the dynamic response of ships in ice and thus acting as a prototype for larger ice-going vessels. For the wider investigation of ice impact loads, consideration should be given to modification and strengthening of the bow to permit it to operate in the elastic range in multi-year ice conditions. To achieve this however, we recommend:

i) Redesign of the bow to meet newly understood response to multi-year ice impact, using non-linear F.E. model techniques.

ii) Selection of bow strength requirement to match the appropriate limiting strength of the current hull girder amidships.

iii) Re-instrumentation of the bow after comprehensive non-linear F.E. analysis.

5) For future programs of this type we recommend that the responsibility for achieving objectives be assigned to one contractor who will design, install, and operate the system, reduce and analyse data and make the final project report.

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"MV ARCTIC"

1981 LATE SEASON DATA COLLECTION AND INSTRUMENTATION

SUMMARY REPORT

7 September 1982

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Prepared for

TRANSPORTATION DEVELOPMENT CENTRE
1000 Sherbrooke Street West
Montreal, Quebec, H3A 2C3

Submitted by

ARCTEC CANADA LIMITED
311 Leggett Drive
Kanata, Ontario, K2K 1Z8

The contents of this report reflect the views of the authors and not necessarily the official views or policies of the Transportation Development Centre.

The Project Team from ARCTEC CANADA LIMITED was composed of:

°I.F. Glen

°H. Blount

°M. Steele

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17. Abstract

This is the report of the operation of the M.V. ARCTIC data acquisition system during the latter part of the 1981 data collection season. During the period, system maintenance levels continued to be high. Principal problems were computer losses due to overheating and failed integrated circuit boards. Gauge drift and video camera problems also were of importance.

A large quantity of data was collected, much of it in heavy ice conditions. Preliminary analysis of this data concentrated on more significant ice interactions, and a new approach to presenting trends in statistical data is presented. A number of sampling patterns were tried and are compared.

Suggestions for techniques to validate data during further analysis are made. A comparison of the data with analogue signals is made. Results indicate that local hull stress levels while backing and ramming in multi-year ice are high - exceeding yield in some instances, two and three times those during transit operations in heavy ice, and up to six times greater than those experienced while transiting level first year ice. It is noted that following in the track of an icebreaker also gives rise to high loading.

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17. Résumé

Ce rapport traite de l'exploitation du système de saisie de données installé à bord de l'Arctic, vers la fin de la saison de navigation de 1981. Tout au long de cette période, le nombre de réparations effectuées a continué d'être élevé. Mis en cause sont les circuits intégrés qui surchauffent et qui grillent, entraînant la perte des données. D'autres ennuis d'importance ont été causés par la dérive du zéro et par la caméra.

Une grande quantité de données a été recueillie, en bonne partie sur une mer très chargée de glaces. Le dépouillement préliminaire a porté sur les effets les plus importants de l'action des glaces, et le rapport propose une nouvelle façon de dégager les tendances dans les données statistiques recueillies. Un certain nombre de méthodes de sondage ont été essayées et comparées.

Le rapport suggère des techniques visant à vérifier la validité des données à l'occasion d'analyses plus poussées. Une comparaison des signaux numériques et analogiques y est présentée. Les résultats montrent que la coque subit des contraintes localisées élevées lorsque le navire recule et fonce dans des glaces de plusieurs années, contraintes qui, dans certains cas, ont dépassé la limite élastique, sont de deux à trois fois plus fortes que celles observées durant la navigation dans des glaces épaisses et qui peuvent être six fois supérieures à celles qui s'exercent sur le navire lorsque celui-ci se déplace dans des glaces de première année, d'épaisseur uniforme. Le rapport signale enfin que des contraintes élevées s'exercent aussi sur le navire lorsqu'il navigue dans le sillage d'un brise-glace.

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FOREWORD

The project reported herein covers the operation and maintenance of the data acquisition system aboard the CASPPR Class 2 ore carrier 'MV ARCTIC' during the latter part of the 1981 data collection season, and preliminary analysis of the data therefrom. The MV ARCTIC is fitted with an onboard data acquisition system designed to collect data on ship performance to ice during normal commercial operations in the Arctic under the CASPP Regulations. This data is to be used to assist designers, operators and regulators.

The system was operated by ARCTEC CANADA LIMITED during the last 2 1/2 Trans-Atlantic voyages from Antwerp to Nanisivik in 1981. The report describes the ship operations, documents the data recorded and provides indications of the maintenance problems and results achieved. The main report bound in two volumes is available as TP 3634.

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1. INTRODUCTION

"MV ARCTIC" is a general purpose ore carrier built to Arctic Class 2 under the current Arctic Shipping Pollution Prevention Regulations. She has an installed data acquisition system which has been used during several voyages into the Canadian Arctic over the last three years to record data on the performance of the ship in ice. The purpose of this installed system is to evaluate the ice breaking features of the vessel for guidance in future designs and to collect data for use by operators and regulators in updating the Arctic Shipping Pollution Prevention Regulations.

For the latter part of the 1981 data collection season ARCTEC CANADA LIMITED was contracted by the Transportation Development Centre to operate and maintain the system and to carry out preliminary data reduction and analysis using the onboard computer. In addition to operating and maintaining the system, the role of the contractor includes documenting the recorded data in a manner which will permit ready access for more detailed analysis later, if desired, and also to give guidance and recommendations on future system operations and data analysis.

The latter half of the 1981 data collection season started on the 28th of August 1981 when ARCTEC CANADA LIMITED staff joined the ship and, following a brief inspection accepted the data acquisition system subject to a number of reservations concerning the system status. The ship, having struck the dock on entering Nanisivik, completed temporary repairs and sailed for Antwerp on the 4th of September. The ship was repaired in Amsterdam returning to Nanisivik during the last week of September. During this period the data acquisition system recorded open water performance parameters in various sea conditions. En route to Nanisivik a seized piston halted the ship for four or five days. The system operator was changed at this point, the ship returned to Europe arriving back on its final round trip at Broughton Island by November 3rd. Up to this point only scattered glacial ice in the form of bergy bits had been sited and no data of significance had been collected. A dedicated test team from Melville Shipping Limited and Ship Safety Branch of Coast Guard joined the ship at Broughton Island for several days of dedicated ice trials in which the ship was subjected to low speed rams against multi-year ice to investigate hull girder response. During the tests, the onboard operator took the opportunity to record some analogue data from strain gauges during the multi-year ice impacts. The final loading at Nanisivik took place on the 9th and 10th of November when the ship sailed through heavy ice conditions taking nine days to reach Cape Farewell. During the period the ship was forced to stop for the night on four occasions. Heavy concentrations of multi-year ice were found in Lancaster Sound from Admiralty Inlet to Navy Board Inlet and around Pond Inlet.

The data acquisition system was finally closed down on November 16th in Davis Strait when only pancake ice was present. This permitted the operator to use the available time to Antwerp to carry out data reduction on a round-the-clock basis.

In the following sections of this summary report a brief description of the data collection activities is given together with a summary of results acquired from preliminary analysis and observations and conclusions drawn from this project.

2. INSTRUMENTATION SYSTEM

The onboard data acquisition system has been described fully in a number of documents and the reader is referred to references [1] and [2] for a detailed description.

System maintenance levels were considered high throughout the season. The principal problems were associated with sensor failures, computer losses due to overheating and failed integrated circuit boards and failure of the video camera system. A significant number of integrated circuits failed during the season. These use CMOS technology which is known to be intolerant to static charge, transient voltages and excessive circuit loading. Continual insertion and re-insertion of circuit boards in an attempt to isolate problems caused transients to occur which cause CMOS chips to fail. This has a cascading effect destroying other previously good chips. The current system also has a great number of connectors connecting these circuits to each other, all of which are in hostile surroundings. Another problem which was experienced was computer failure at elevated room temperatures. The fundamental reason for this was never established but experience indicated that cooling the computer room to 65 degrees Fahrenheit prevented the problem. This problem, like the previous one, had been previously reported but recommendations for improvements had not been carried out.

Strain gauges constitute the majority of sensors for the data acquisition system. These are subject to an unusual amount of drift, and with the current system rebalancing these gauges at the junction box is a tedious process. The pan-tilt zoom television system failed due, it appeared, to corrosion in the environmental housing. This latter was open to the atmosphere through holes provided to ventilate electronic parts contained inside.

A detailed maintenance log has been provided in the main report along with our operator's proposals for onboard system checks and troubleshooting. Notwithstanding this however, the system appears to be subject to an unusually high amount of maintenance through a combination of design and installation which did not account for the hostile environment, and the natural aging process.

During the late 1981 data collection season a total of 47 data tapes were recorded representing some 82 hours of data, the majority in ice covered waters. These are summarized in Table 2.1 along with descriptions of the prevailing ice conditions and sampling patterns. Of the 32 tapes and 55 hours of data recorded in ice, only 24 of these were reduced statistically using the onboard computer during the ship's last Atlantic crossing. These tapes were selected as those which represented the widest variety of ship/ice encounters and for which the onboard operator judged the data quality was superior due to lack of system crashes and other external influences. It will be noted that in view of the large amount of data collected, the amount of data reduced onboard was limited by the available time from the final recording session to the arrival of the ship in Antwerp. The system operator reduced data around the clock for 11 days.

TABLE 2.1

TAPE SUMMARY

	TAPE	NO. OF FILES	DATE-TIME (GMT)	TOTAL PERIOD	REDUCED PERIOD	PREDOM. SAMPLING PATTERN	DESCRIPTION
	1	4	9/6/81-1700	35 min.	35 min	A	Nanisivik Dock and light seas.
	2	7	9/7 & 8/81	66 min.	66 min	A	Light seas
	3	2	9/9/81	57 min.	57 min	A	Moderate ahead seas with roll
	4	16	9/17 & 18/81	43 min.	40 min	A	Maneuvering in Antwerp
	5	1	9/26/81	3 hrs.	3 hrs.	A	Maneuvering open water
	6	4	9/28	40 min.	40 min	A	Moderate to heavy seas
	7	4	10/5/81	30 min.	15 min	A	Docking in Nanisivik
	8	2	10/17/81	1 hr.	1 hr.	A	System tests in open water, no roll.
	9 & 10	Re-used	at later date				
	11	1	10/18/81	47 min.	-	B	Docking in Antwerp - system test.
	12	7	10/22-23/81	1 hr.	-	B	Leaving Antwerp - Tests with "LIPS"
	13	7	11/3/81	4 hrs	-	E	Young ice/1st yr.6-8"
	14	3	11/3/81	30 min.	-	B	10/10 coverage 1st year ice.
	15	4	11/4/81	2 hrs.	1 1/2 hrs	B,C	Open water & multi-year rams.12"1styr.48"2nd zero shift on 4 gauges
	16	3	11/4/81	2 hrs.	2 hrs.	B,C	6/10 1st year, 3/10 multi-year.
	17	3	11/4-5/81	1 3/4 hrs.	-	B,C	6/10 1st year, 3/10 multi-year.
+	18	2	11/6/81	1 1/2 hrs.	-	B,C	Backing & ramming (Trials).
+	19	9	11/5-6/81	1 1/2 hrs.	1 1/4 hrs	I,B	Backing & ramming & continuous transit.1styr 2"snow,8"ice,myr 4-6'*
	20	3	11/6/81	2 hrs.	1 1/2 hrs	B,C	Continuous 1st year transit, loose pack.
	21	1	11/6/81	2 hrs.	-	C	Continous transit, loose pack.
+	22	5	11/7/81	1 1/2 hrs.	3/4 hrs	B	Backing & ramming, loose back, 2/10 MY-16' 1st yr-6-8"

*zero shift on 3 channels

TABLE 2.1 CONTINUED
TAPE SUMMARY

	TAPE	NO. OF FILES	DATE-TIME (GMT)	TOTAL PERIOD	REDUCED PERIOD	PREDOM. SAMPLING PATTERN	DESCRIPTION
+	23	1	11/7/81	20 min.	20 min	B	MY ram at high sampling rate.
+	24	3	11/7/81	1 1/2 hrs.	1 hr	B,F	Backing & ramming MY floe (20 ft). 1st yr 8-10"
+	25	7	11/7/81	1 1/2 hrs.	-	F,B	Backing & ramming continuous transit (lopse 1st year pack) (1.5 snow, 12" ice
+	26	2	11/8/81	3 hrs.	3 hrs	C	Backing & Ramming 2/10 MY, 1st yr 5" snow 9" ice
	27	1	11/8/81	1 hr.	1 hr	B	Continuous transit, 8/10 1st year
	28	1	11/8/81	1 hr.	1 hr	B	Continuous 1st yr transit, Admiralty Inlet.
	29	3	11/8/81	2 hrs	2 hrs	G,H	Doppler CALS in Adminalty Inlet, 1-2 ft 1st yr
	30	1	11/8/81	2 hrs	-	C	Maneuvering into Nanisivik
	31	1	11/11/81	3 hrs.	-	C	Leaving Nanisivik, 1st year ice.
	32	1	11/11/81	2 1/2 hrs.	2 min	C	9/10 coverage, 1st year with ridging. Zero shift on 2 gauges
	33	1	11/12/81	2 hrs.	2 hrs	C	1st year & MY ice, looking for LOUIS track
	34	1	11/12/81	2 1/2 hrs.	-	B,C	in LOUIS track but MY impacts.
	35	1	11/12/81	2 1/2 hrs.	-	B,C	In LOUIS track in MY ice
	36	2	11/12/81	2 hrs.	2 hrs	I	Backing & ramming in MY with milling.
	37	1	11/12/81	50 min.	15 min	I	Backing & ramming with heaving milling.
	38	1	11/12/81	1 1/2 hrs.	3/4 hr	B	Backing & ramming
	39	3	11/12/81	2 1/2 hrs.	2½ hr	B,C	Backing & ramming & continuous transit in LOUIS track.
	40	1	11/12/81	1 hr.	1 hr	B	Ramming in LOUIS track.

+ ICE TRIALS

TABLE 2.1 CONTINUED

TAPE SUMMARY

TAPE	NO. OF FILES	DATE-TIME (GMT)	TOTAL PERIOD	REDUCED PERIOD	PREDOM. SAMPLING PATTERN	DESCRIPTION
41	1	11/12/81	2 hrs.	1 hr	G	Backing & ramming, ice milling.
42A	1	11/12/81	1 1/2 hrs.	1½ hr	G	Backing, ramming, milling.
42B	1	11/13/81	3 hrs.	Fatal run time errors	C	Backing & ramming.
43	3	11/13/81	3 hrs	2 hrs	C	Backing & ramming in front of iceberg.
44	2	11/13-14/81	2 hrs	-	B,C	Backing & ramming maneuvering in berg field and also backing & ramming in pack MY ice. 1st&2nd yr 2-4 ft
45	1	11/14/81	30 min.	30 min	B	High rate, backing & ramming in pack ice.
46	1	11/15/81	3 1/2 hrs.	2 hrs	C	Following in LOUIS track.
47	5	11/15/81	2 1/2 hrs.	-	J,C	Ramming in 1/10 MY 1 mile visibility.
48*	2	11/15/81	1 hr.	-	D,C	Backing & ramming 1/10 MY.
49**	2	11/15/81	3 hrs.	-	C	LOUIS track, 1st year, 8/10 coverage. 6-8"thick

*Tape No. 9 re-used

**Tape No.10 re-used

During the data acquisition period, the sampling pattern which represents the sequence and frequency in which the computer collects data from the many sensors, was adjusted ten times. These are described in Table 2.2 along with the rationale for their selection.

In addition to the onboard data acquisition system, an eight channel analogue FM recorder was provided by the contractor. This was used to compare the digitized output from strain gauges with the analogue form in order to better understand and make corrections for the data recorded on the digital system. In addition, this recorder was operational during the dedicated trials period in which head-on rams were executed, providing useful information on the time hitories of strain signals including rise times and duration, for those involved in seeking greater understanding of the ship/ice interaction.

TABLE 2.2

SAMPLING PATTERN SELECTION

RATE PATTERN	PATTERN SUMMARY	OBJECTIVE
A	High Rate on 7 Strain Gauges	Used in Backing and Ramming Conditions - to capture time series strain data during impact
B	High Rate on 7 Different Strain Gauges	
C	Peak Mode on All Strain Gauges	Used in continuous transit lst yr ice - to collect general statistics
D	Time Series on 7 Different Gauges	As for A and B
E	Peak Mode on All Strain Gauges and Accelerometers	Ship Response in lst yr ice, 4/10 coverage
F	High Rate on Thrust and Torque	To capture ice milling incidents; unable to detect ice milling
G	High Rate on Accelerometers	To capture dynamic hull response during ramming with noticeable ship bending
H	Propulsion and Ship Speed Only	Doppler Log Calibrations
I	High Rate on 7 gauges and Torque and Thrust	Backing and Ramming with Milling
J	High Rate on Mid Ship Gauges	To capture hull bending during ramming (noticeable ship bending.

3. DATA REDUCTION AND ANALYSIS

Data analysis took the form of extraction of statistical parameters from the most significant tapes. These parameters included maximum and minimum values, average values, rms values and standard deviation for the scanned channels. This statistical data has been reproduced for forty periods of ship/ice encounter from 24 data tapes and they are provided in computer print-out form in a separately bound volume. The tapes and files reduced statistically are shown in Table 3.1.

In addition, 14 periods were subjected to further analysis in an attempt to develop a useful technique for using the data to examine the relationships between various parameters which may be of value to ship designers. To achieve this a number of parameters were defined which it was considered were indirect measures of ship structural performance. These are listed in Table 3.2. These parameters are indirect indicators of load activity, magnitude and impact pressure which are a few of the main factors of interest to the designers of structure against ice loads. Others include, of course the load rise time and duration, and the dynamic characteristics of the structure.

Although the system as fitted cannot provide direct values for these factors due to gauge distribution and lack of suitable calibration, the following explains how the parameter chosen can be assumed to relate to the desired factors:

> The two parameters FR > 100 μS and PL > 100 μS (especially the latter) are an approximate indication of the area of the hull over which the ice was acting during statistical period. They are thus a measure of activity intensity only.
>
> Since the normal conversion of measured structural strains to ice loads is via algorithms in which ice loads are expressed as a function of sums, averages, or products of combinations of measured strengths, the parameters SR SUM, FR AVE, and FR MAX are an approximate indication of the magnitude of the maximum load experienced during the statistical period. Finally the parameter PL MAX will provide information on the degree of local loading in the plate and hence may be considered an indication of ice pressure.
>
> Other parameters of direct interest are the ship velocity both average and maximum and the ship's average and maximum thrust.

The values of these parameters for the fourteen cases examined which are classified as continuous transit (CT), and backing and ramming (BR), are shown in Table 3.3. Table 3.4 describes the scenarios covered by these fourteen cases.

TABLE 3.1

STATISTICALLY REDUCED DATA

CONDITIONS	REDUCED PERIOD [MIN]	TAPE #	FILE #
Open Water	35	1	00 to 03
	66	2	00 to 06
	57	3	00, 01
	40	4	00 to 15
	180	5	00
	40	6	00 to 03
	15	7	00 to 03
	60	8	00, 01
	Total # hrs = 8.2		
1st Yr Ice Continuous Transit	90	15	00
	60	27	01
	60	28	00
	120	29	01, 02
	120	46	00
	Total # hrs = 7.5		
Backing and Ramming in MY ice	75	19	01
	90	20	00, 01
	45	22	00
	20	23	00
	60	24	00, 01
	180	26	00, 01
	45	38	01
	120	43	00, 01
	30	45	00
	Total # hrs = 9.6		
Backing and Ramming MY ice, ice milling	120	36	00,01
	15	37	00
	60	41	00
	90	42A	00
	Total # hrs = 4.8		

TABLE 3.2

FR > 100μS:		The number of frame gauge reading greater than 100 μS during the statistical collection period.
FR SUM	:	The sum of the frame strain maximums.
FR AVE	:	The average of the frame strain maximums.
FR MAX	:	The maximum frame strain.
PL > 100μS:		The number of gauges greater than 100 μS.
PL MAX	:	The maximum plate strains.
VEL AVE	:	The average ship speed (knots).
T AVE	:	The average thrust in metric tonnes.
VEL MAX	:	The maximum ship speed.

TABLE 3.3

RESULTS OF STATISTICAL ANALYSIS FOR SELECTED CASES

TAPE OBSERVATION NO TAPE NO.	CT#1 16-C	BR#1 19E-1	CT#2 20-A	CT#3 20-B	BR#2 22-A	BR#3/CT#4 26-A	BR#4 26-B	CT#5 27-B	CT#6 28-A	CT#7 28-B	CT#8 32-A	BR#5 36-A	BR#6 36-B	BR#7 38-B
NO. OF FRAME GAUGES OVER 100 μS (#FR > 100 μS)	5	11	31	30	25	29	16	38	40	38	10	41	34	27
SUM OF FRAME GAUGES OVER 100μS (FR SUM)	3040	2465	11580	5730	7422	11500	3110	11420	17000	10165	8214	21339	12575	10883
FRAME AVERAGE (B/A) (FR AVE)	608	224	373.5	191	296	396	194	293	425	267.5	821.4	520	369	403
MAXIMUM FRAME STRAIN (FR MAX)	2000	300	1300	860	790	1140	380	670	1665	950	1762	1400	1240	1014
NO. OF PLATE GAUGES OVER 100μS (PL > 100μS)	5	6	19	17	14	15	6	20	19	20	11	26	15	15
MAXIMUM PLATE STRAIN (PL MAX)	270	300	800	620	800	915	350	850	1200	950	1856	1750	1400	1804
MAXIMUM SHIP SPEED (KNOTS)	4.0	16.32	12.72	6.3	3.40	6.09	6.91	29.77	16.73	6.21	7.62	11.69	4	2.90
MINIMUM SHIP SPEED (KNOTS)	1.5	1.38	0.70	0	0.39	0	0	0.09	0.88	1.44	4.22	0	0.0	0
AVERAGE SHIP SPEED (KNOTS)	1.0	6.5	6.82	3	1.52	2	2.2	8	6.6	4.6	5.88	1.28	2.2	0.79
AVERAGE THRUST (TONNES)	1.83	81.96	69.40	32	70.31	55	52	38	44	41.69	35.8	77	82	83.9
DURATION OF STATISTICAL OBSERVATION (MINS)	23	3	17	53	26	110	70	77	48	7	7	101	24	46

TABLE 3.4

CASE DESCRIPTIONS

OBSERVATION	TAPE I.D.	DESCRIPTION
BACKING & RAMMING		
BR#1	19-E	In 3/10 MY, 8/10 1st year
BR#2	22-A	1-4 knots (3 knots average)
BR#3	26-A	1-3 knots, 8/10 1st yr, 2/10 MY
BR#4	26-B*	(10 min) plus 5 knots continuous in 1st year.
BR#5	36-A	In LOUIS track, 1st year & 2/10 MY
BR#6	36-B	Heavy going in pack ice
BR#7	38-B	1st year and MY pack ice
CONTINUOUS TRANSIT		
CT#1	16-C	6/10 1st yr, 3/10 MY cont. transit
CT#2	20-A	8-10 knots 1st yr/ 1-4 knts Loose Pack (1/10 MY)
CT#3	20-B	2-5 knots 9/10 1st yr with leads/ Rams in MY rub.
CT#4	26-B*	Backing & ramming (10 min)/5 knots continuous in 1st year
CT#5	27-B	1st yr, 1/10 MY, 8/10 coverage continuous transit, 8 knots
CT#6	28-A	1st & 2nd yr ridged ice 3- 10 knots continuous transit
CT#7	28-B	7 knots 8/10 coverage 1st & 2nd yr loose pack
CT#8	32-A	4 knots continuous transit.

*Used in both backing and ramming and continuous transit cases.

Regression analysis of these various parameters was performed and is presented in the main report. The results indicate that the magnitude of loads on the hull as indicated by the values of plate and frame maximum strains, increases with the degree of loading activity as indicated by the number of plate gauges exceeding 100 micro strain. In continuous ice transit the magnitude of loads is linearly proportional to the average velocity in the transit. However, in backing and ramming this relationship is not obvious due to the discontinuous nature of the operation. The average thrust record did not correlate well with the average velocity record even during continuous transit. This is a reflection of the difficulty which is seen in selecting a meaningful return period for statistical data during which parameters do not vary significantly.

Strain gauges exceeded yield on a number of occasions both on the frames and on the plates. Of the fourteen cases selected, eleven indicated cases where frame stresses were greater than half allowable yield stress and two returned maximum frame stresses beyond yield. In the case of plate gauges, four of the cases exceeded yield and once more eleven exhibited incidences where strains exceeded half of yield. This indicates that the cases selected were indeed those representing significant ice incidences and that the operators onboard selection was most appropriate. It should also be noted that in cases where yield was exceeded subsequent analysis must take care to ensure that the results from rebalanced gauges are meaningful.

It was noted that when operating in the broken track from an icebreaker under dynamic ice conditions a considerable amount of strain activity took place. Indeed strain levels over half of allowable yield were recorded under these conditions.

The recording of ship's speed by the doppler log appears to be unreliable. The statistical output can register spurious speed readings which if not noted and corrected by reference to adjacent values or the video record may greatly affect the statistical analysis.

This form of statistical analysis in which trends between one statistical parameter and another are examined may be useful in projecting the relationships of significant ship performance parameters to ship and ice conditions not falling within the recorded period. It offers an alternative to the presentation of histograms although this latter technique may be suitable where an adequate amount of data is available for projection of extreme values. In this report the examination of trends between parameters was used as a means of assessing the quality of the data recording, reduction and preliminary analysis, as it was felt that unusual trends or the non-existence of trends where they were expected would be an indication of appropriate selection of the statistical return period. A qualitative comparison of the strains on the hull between a case of backing and ramming in multi-year ice and level ice transit was made. This graphical representation shown in Figure 3.1 indicates the relative magnitude of strains in both the frame (Figure 3.1a) and plate (Figure 3.1b) between the two ship ice conditions. For each location the left bar represents the strain level in the backing and ramming condition and the right bar of that in the continuous transit case. Strains below 100 micro strain are ignored.

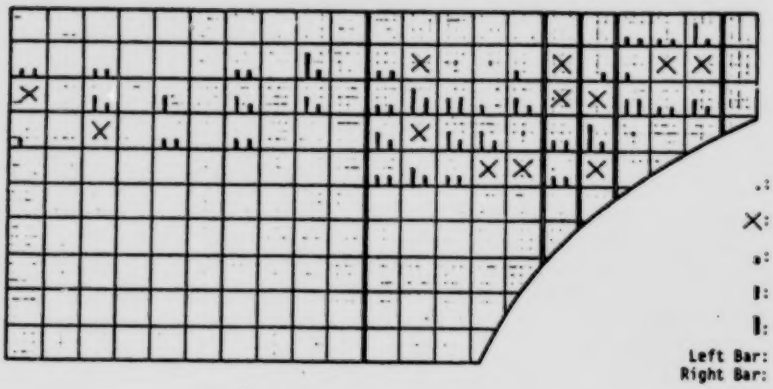
FIGURE 3.1

(A)

COMPARISON OF BACKING AND RAMMING
AND CONTINUOUS TRANSIT: FRAME STRAINS

BACKING AND RAMMING
November 12, 2318-0105 GMT 7/10 1st yr, 1/10 2nd yr, 2/10 MY in pack ice

CONTINUOUS TRANSIT - November 8/81
8 knots
8/10 1st yr, 2/10 MY

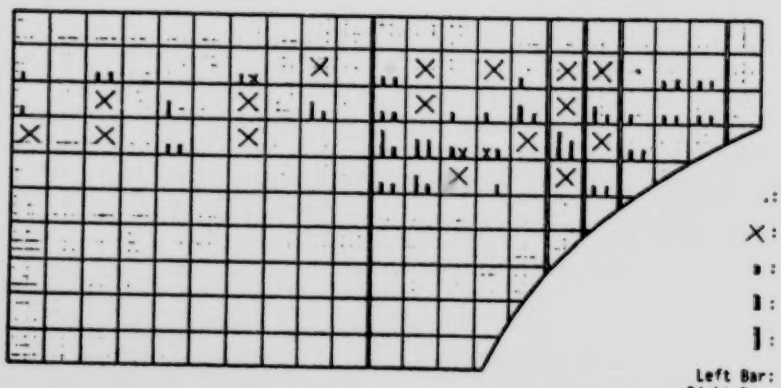


(B)

COMPARISON OF BACKING AND RAMMING
AND CONTINUOUS TRANSIT PLATE STRAINS

BACKING AND RAMMING
November 12, 2318-0105 GMT 7/10 1st yr, 1.5/10 2nd yr, 1.5/10 MY in pack ice
(see Gen. Log)

CONTINUOUS TRANSIT - November 8/81
8 knots
8/10 1st yr, 2/10 MY



Strains are categorized as being below 500 micro strain, between 500 and 1000 micro strain, and above 1000 micro strain. As will be seen the level of strains in the backing and ramming mode are somewhat higher than those experienced during level ice transit.

Data analysis was also performed for a number of cases where distinct and discrete impacts against multi-year ice were recorded. Using the onboard analogue tape recorder the time histories of strains in a group of strain gauges between frames 183 and 185 were examined. These are shown in Figure 3.2. This output clearly indicates the zero shift resulting from strains beyond yield, rise times of around .7 seconds and the movement of the impact across the hull.

Comparison of the analogue records with the digital records for identical periods indicated that in general the analogue recorder returned strain levels somewhat higher than those reported via the computer. This is shown in Table 3.5 for a single impact case which occurred on November 8, 1981.

In Table 3.6 are reproduced in tabular form the results of time history analysis for a number of gauges during several discrete impacts. Examples of some time histories are reproduced in Figure 3.3. These are not necessarily the same incidents as analyzed in Table 3.6. Finally, during discrete ramming tests carried out for Canadian Coast Guard by Melville Shipping Limited in which the MV ARCTIC was driven head-on into multi-year ice and large first year ridges was shown that the gauges on the shoulder of the vessel forming part of the onboard data acquisition system recorded virtually no strain. Gauges fixed to the main deck amidships were reported to have recorded significant strains during these head-on rams. No local loading was evident. The reverse was also true in that incidences which caused heavy strains in the shoulders of the vessel were not noted on the midship gauges necessarily. The uncoupling of these two data recording sets clearly indicates that the problem of ice loading on ships falls into two distinct categories, one being the design of structure locally to withstand impact and the other being the overall design of the hull girder to withstand major ramming incidents. It would also seem apparent that strain gauging of selected areas of the hull is not appropriate if total load in a global sense is to be measured.

Finally, based on the experience of ARCTEC CANADA LIMITED during this short period onboard, recommendations are made in the main report for the procedure to be followed during subsequent data analysis. The importance of pre-screening the data is stressed as it is felt that careful scrutiny of all output is required to identify spurious data such as that sometimes recorded by the doppler log, zero shifts in strain gauges, and anomalies arising from intermittent computer system shut down. In addition, when analyzing data statistically great care must be taken in selection of the statistical return period to ensure that changing ice or ship conditions are not permitted to influence the value of the statistical data.

FIG. 3.2

ANALOGUE PLAYOUT OF 2ND IMPACT

NOV. 6
1850 HRS.

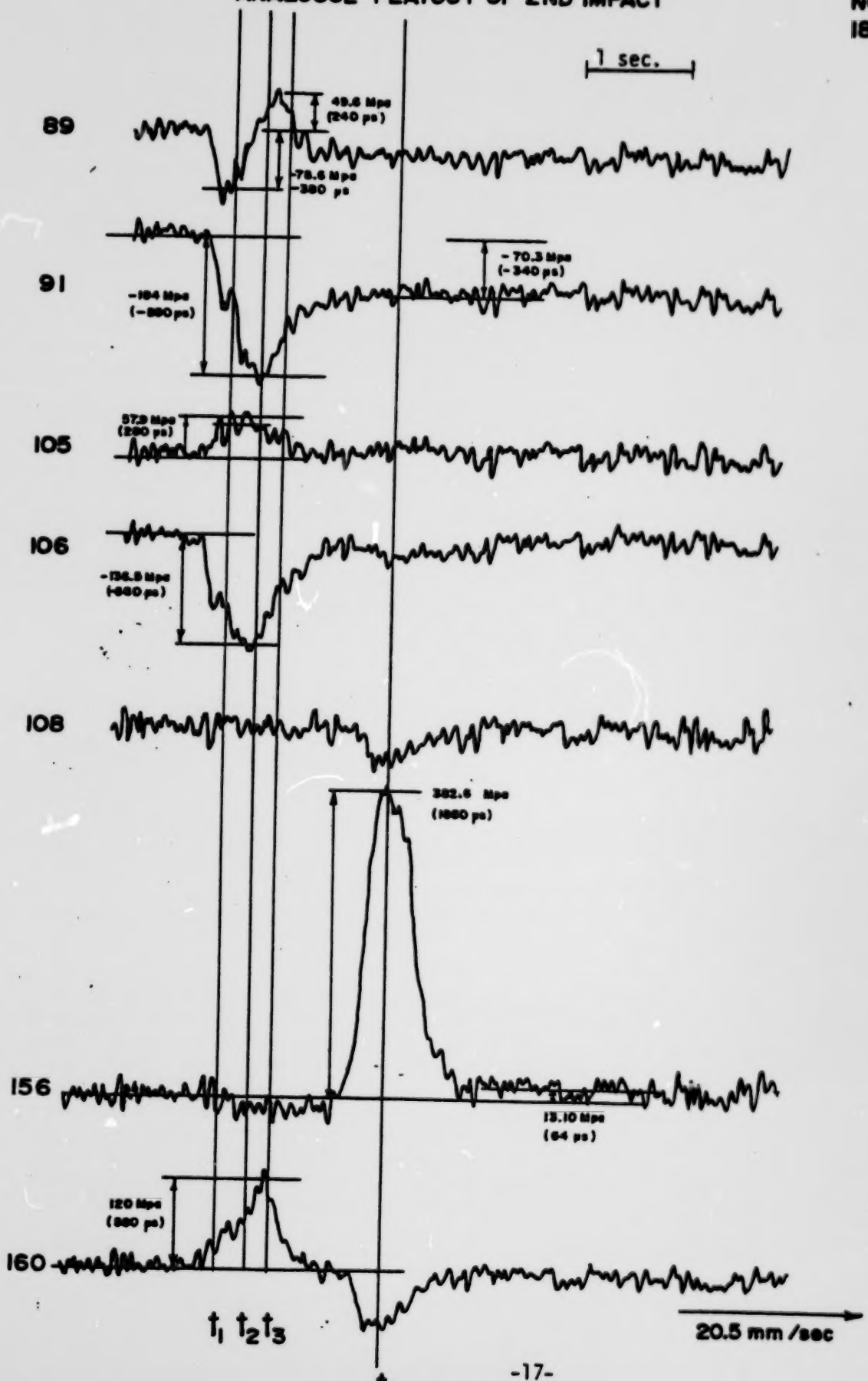


TABLE 3.5
COMPARISON OF DIGITAL AND ANALOGUE PEAK STRAINS

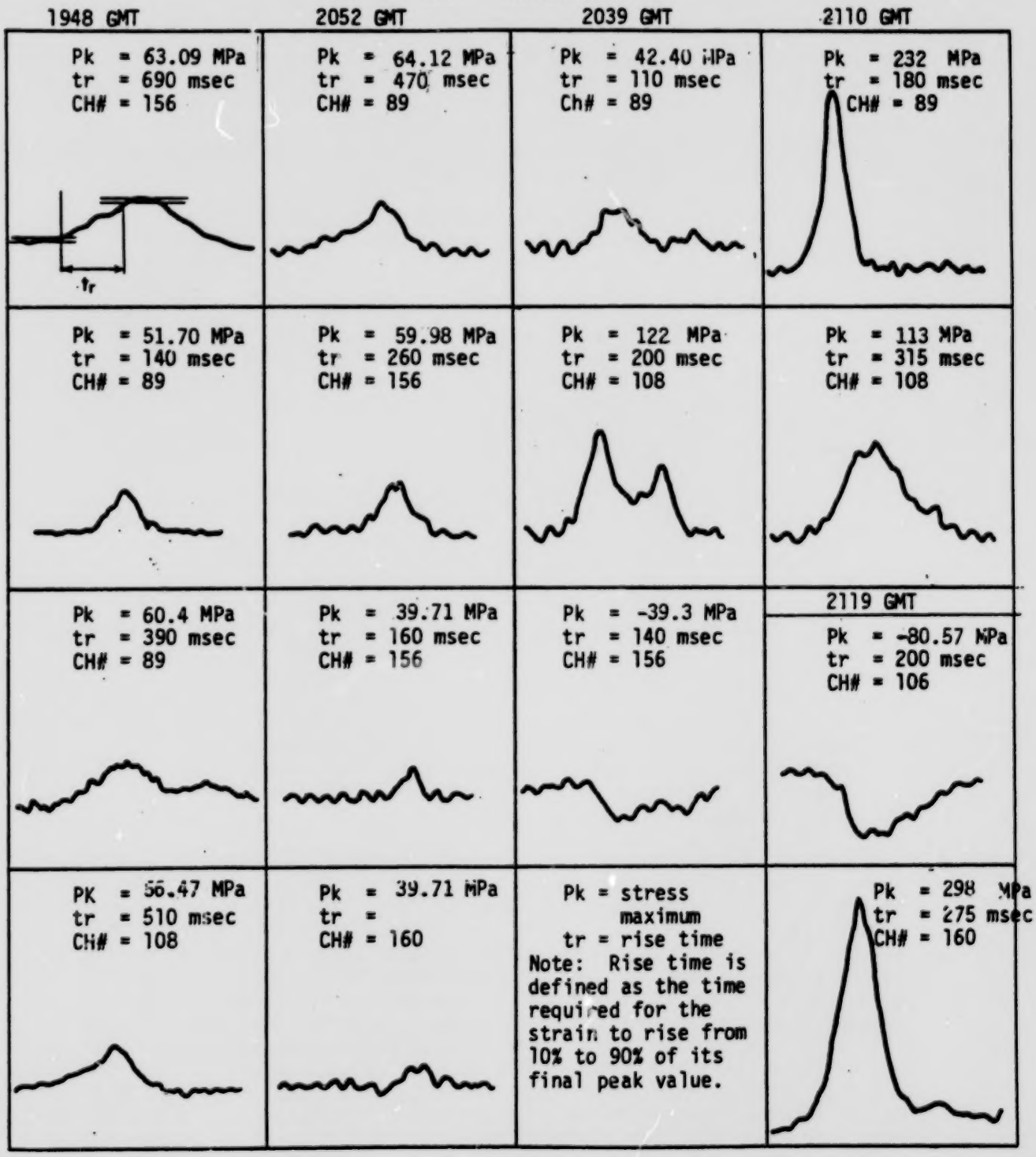
COMP / REC. CHANNELS		MAXIMUM COMP. / REC.	
89	1	950μS	1120μS
91	2	-	0
105	3	-	0
106	4	-	0
108	5	-	546μS
156	6	170μS	290μS
160	8	180μS	305μS

TABLE 3.6
STRAIN HISTORY DATA

CHANNEL/FRAME		PEAK STRESS/ STRAIN	RISE TIME [msec.]	STRAIN DURATION [msec.]	NOV.8/81
89	Main	51.70 MPa (250μS)	140	335	1948 hrs
89	Main	60.40 MPa (292μS)	390	1560	"
108	Web	56.47 MPa (273μS)	510	768	"
156	Main	63.09 MPa (305μS)	690	1300	"
89	Main	64.12 MPa (310μS)	470	810	2052 hrs
156	Main	59.98 MPa (290μS)	260	551	"
156	Main	39.71 MPa (192μS)	160	217	"
89	Main	42.40 MPa (205μS)	110	433	2039 hrs
108	Web	122.04 MPa (590μS)	200	866	"
156	Main	-39.30 MPa (-190μS)	140	768	"
106	Web	-80.67 MPa (-390μS)	200	1122	2119 hrs
160	Main	297.85 MPa (1440μS)	275	709	"
89	Main	231.66 MPa (1120μS)	180	394	2110 hrs
108	Web	113.07 MPa (546μS)	315	1043	"

FIGURE 3.3

TYPICAL STRAINS
November 8/81 ANALOG RECORDER



4. CONCLUSIONS AND RECOMMENDATIONS

(1) Based on the half season operating experience of ARCTEC CANADA LIMITED it is concluded that the MV ARCTIC data acquisition system requires an excessive maintenance effort in return for which the value and quality of the data and the quantity of data appears somewhat inadequate. Whereas some of the maintenance problems may be attributable to aging (which items have been identified) poor system component choice or installation are certainly responsible for many of the problems. Many of the problems noted have been previously reported but no action taken to correct or alevíate them.

> Modification and improvement of the MV ARCTIC data acquisition system is recommended before further data collection seasons take place.

(2) Loads measured by the onboard data acquisition system are those associated with local impact during head-on ramming in heavy ice. Loads on the hull which cause bending in the overall hull girder are not detectable by the current data acquisition system. It is concluded therefore that the system as fitted may provide information concerning the design of local structure against ice loads but will not provide information relating to the overall response of the ship to impact.

> In the design of the data acquisition system the clearly separate objectives of examining local structural impacts or overall response of the ship to global loads must be identified and the data acquisition system designed appropriately.

(3) Load levels experienced during operations following the track of an icebreaker in dynamic ice conditions were moderately high with stress levels beyond half yield being recorded on such occasions.

> The scenario wherein a ship is following in the wake of an icebreaker is significant to the design of ice transitting ships and may require further study to ensure that the acceptability of lesser strength levels for ships travelling in convoy is justified.

(4) Strains experienced by the MV ARCTIC while moving in multi-year ice were of the order of two to three times those experienced in the wake of an icebreaker and three to five times those experienced during level ice transit. On a number of occasions, stresses in frames and plates exceeded yield while moving through heavy ice towards the end of the season. Permanent set was experienced in the hull of MV ARCTIC during this portion of the season not necessarily during dedicated tests ramming in multi-year ice. It would appear therefore that the design of the structure under the CASPPR for a Class 2 ship operating towards the end of its permissable period in the zone is at best marginal, and that under any circumstances other than the best navigational ones the chances of permanent damage to the hull are not insignificant. On the other hand the configuration of the MV ARCTIC is such that it is capable of providing most useful data on the response of ships in ice and acting as a prototype for larger ice going vessels.

Continued use of the MV ARCTIC to study ship ice impact loads is recommended but consideration should be given to modification and strengthening of the bow to permit it to operate in the elastic range in multi-year ice.